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European house price deviation: infectivity and the momentum effect

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ABSTRACT

This study investigated whether house price deviation (irrational house prices) between European countries is mutually contagious or whether irrational behaviour in relation to house prices is mainly caused by domestic factors. This study investigated eight eurozone countries and the United Kingdom's (U.K.) house price deviation was estimated using the house price–income model, after which the price deviation in each country was analysed and divided into the components of self-influence and influence from other housing markets. The U.K.'s house price deviation was discovered to have the greatest impact on the other European housing markets, whereas France's house price deviation was the most affected by the other housing markets. Italy's house price deviation was the least relevant to the other markets with a 95.5% rate of change and susceptibility to domestic changes. This study quantified the dynamic assessment for infectivity and self-influence in relation to house price deviation and discovered that apart from Italy, whether other countries' levels of infection in relation to house price deviation were significantly correlated to their domestic inflation rates. Finally, the empirical results of this study indicate that the U.K.'s high inflation rate had a significant impact on the imbalance in the eurozone housing markets.

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1. Introduction

Correlation in the international housing market is a crucial topic. If house prices in different countries have low correlation, traders can substantially reduce their level of investment risk by investing in the transnational housing market or transnational property derivative securities. In particular, the prevalence of transnational investment after 2000 has resulted in a scarcity of low-correlation assets on an international scale. Because of non-mobility, low liquidity, high cost and the potential regulatory policies of each country's housing market, real estate has the potential for low transnational correlation. However, the subprime mortgage crisis in the United States (U.S.) in 2007 illustrated a correlation between properties in the U.S. properties and those in other

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countries or other types of assets. Thus, this study investigated whether European countries are still incentivised to reduce the level of transnational investment risk.

Gupta, André and Gil-Alana (2014) used quarterly house price indices from eight European countries between 1971 and 2012 to explore the comovement phenomenon in relation to house prices in European countries and discovered that the European Union's combined house price index had a cointegrating relationship with house prices in Belgium, Germany and France. Other combinations included country pairs such as Belgium and Spain, Belgium and the Netherlands, Germany and Spain, Germany and Ireland, France and Spain, and Ireland and the Netherlands, where house prices in each country exhibited comovement. Despite the empirical results of Gupta et al. (2014) providing evidence for the correlation of housing markets in different European countries, numerous questions were left unanswered. The present study argued that a more crucial research objective than verifying the cointegration between house prices is determining whether the comovement phenomenon in relation to house prices increases the level of risk and determining the structural factors that affect risk. Therefore, this study explored: (1) whether irrational behaviours exist in relation to house prices in European countries; (2) whether the deviation of house prices from fundamentals (unreasonable house price fluctuations) is mutually contagious or whether house price deviation is self-correcting; (3) which countries infect other countries through domestic house price deviation; and (4) which countries' house price deviations are susceptible to domestic factors. Finally, this study explored the main factors of the contagiousness of house price deviation and self-influence.

In theory, correlation between transnational housing markets should be lower than that between other transnational asset markets because housing, unlike financial instruments and general commodities, do not enable investors to engage in arbitrage across the globe. Furthermore, differences in housing market systems and investors' preferences between various countries lead to segmentation between transnational housing markets. For instance, Augustyniak et al. (2013) observed that European countries with a relatively low per capita gross domestic product had a relatively high percentage of owner-occupied properties and illustrated the correlations among housing policies, housing availability, consumption, and household savings. André et al. (2017) identified that asymmetry in housing prices varies between emerging and advanced economies; downward nominal rigidities were present in most of the advanced economies. Since theoretically, housing markets of different countries should be set apart, increased correlations between countries may indicate irrational or unreasonable contagion in housing markets.

For example, correlations between housing markets drastically increase during financial crises (Bond, Dungey & Fry, 2006; Hui & Chan, 2013; Mun, 2005). Thus, the aforementioned studies defined an increased correlation between housing markets as a consequence of contagion effects. By investigating the co-movement of real estate returns in Mexico, Asia, Russia and Brazil during their respective financial crises, Mun (2005) detected evidence of significant contagion effects between Hong Kong and Japan, Hong Kong and Singapore, and Japan and New Zealand in all of the four financial crises except for the Brazilian crisis. When examining the correlations among real estate markets in Australia, Hong Kong, Japan, Singapore and the U.S.

during the 1997–98 financial crises, Bond et al. (2006) found that Hong Kong suffered the largest consequences. Using the Forbes–Rigobon test, Hui and Chan (2013) examined the contagion across European real estate securities markets during the European sovereign debt crisis to identify the investment risks occurring in these markets during that period and reminded investors of readjusting portfolios during a financial crisis.

Previous studies on the European housing market have mainly been divided into two directions, one of which focuses on whether housing markets are correlated (e.g., Hiebert and Roma, 2010; Vansteenkiste & Hiebert, 2011; Gupta et al., 2014), and the other of which analyses the impact factors of house prices in various European countries (e.g., Hiebert & Sydow, 2011; Ott, 2014). The other research direction often overlooked is the initial explanation of house prices through fundamental factors followed by a discussion regarding the correlation between house price deviations in different countries. The reason for not conducting a direct discussion regarding correlation among house prices is the abundance of evidence provided in numerous studies. In addition, if the discussion of house price correlation is based on the motive of measuring investment risk or transnational systemic risk in the overall economy, estimating risk directly through house prices is prone to biases; if two countries are correlated in terms of simultaneous economic growth, such correlation does not necessarily increase risk. Therefore, this study maintained that correlation should be observed through irrational house price behaviours and that correlation between transnational house price deviations is a contagious effect (irrational correlation). If house price deviation is subjected to self-influence, persisting house price deviation indicates that the deviation has momentum and will influence the risk of future house price correction.

Risk forecasts and warnings are most crucial for asset holders and merely proposing the existence of risk based on past data does little to facilitate practical investment. Market participants need to know the trends of market volatility and the factors affecting these trends. Lai and Van Order (2010) analysed the U.S. housing market bubble in 1995–2005 and asserted that the U.S. price-to-rent ratio is affected by fundamental factors such as the degree of interest rate fluctuation during lag periods and the anticipated rental growth rate. The error term of the model follows the self-correlation characteristic and the sum of the regression coefficient for the lag period error term can determine the impact of exogenous shocks on the price-to-rent ratio, where a positive coefficient sum illustrates that the exogenous shocks provide momentum for positive deviation of the price-to-rent ratio from the fundamentals. After estimating installment, Lai and Van Order (2010) proposed that the housing market bubble began in 2003 and was related to the existing subprime market prosperity and lower short-term interest rates. The researchers explained that the deviation of the price-to-rent ratio, or in other words, the deviation of house prices relative to rent prices, may have momentum that leads to the formation of bubble risk. The present study argued that house price deviation should be quantified using the rolling dynamic method, which can clearly distinguish between the contagious effect and self-influence of house price deviation at distinct time points to objectively verify the source of housing market risks.

This study estimated house price deviation through the vector autoregressive (V.A.R.) model. By analysing the rolling computations of variance decompositions of the forecasted error covariance of the V.A.R., we estimated the diagonal elements, indicating the self-influencing impact, and the rest of the decomposed error covariance matrix which indicates the interacting influence across countries. Changes in house price deviation can be differentiated self-influence (momentum effect if persistent) and based on influence from other countries (contagious effect). Then, the present study went on investigating the impact of inflation rate and interest rate on the contagious effect and self-influence to systematically analyse the causes of contagious and momentum effects.

The remainder of this article is organized as follows. [Section 2](#) reviews the relevant literature on house price deviation, particularly focusing on articles that have used European house prices as samples, and reviews studies that have explored correlation among European house prices. [Section 3](#) describes the samples and estimates the house price deviation. [Section 4](#) describes the estimation of the contagious effect and self-influence and verifies whether both are affected by money illusion and interest rate. Finally, [Section 5](#) provides a conclusion.

2. Literature review

2.1. House price deviation

House price deviation refers to the deviation of house prices from the fundamentals and can be regarded as the difference between the actual house price and that after deducting the equilibrium level as measured based on the fundamentals (rational house price). Short-term house price deviation is often attributed to low liquidity within the housing market, whereas comparatively long-term house price deviation or the trending of house price deviation is generally explained through irrational trader behaviours. Hott (2012) analysed whether investors' herd behaviours can be used to explain house prices deviating from the fundamentals by analysing samples from 10 countries including Australia, Spain, France, Japan, the United Kingdom (U.K.) and the U.S. The data included real house prices, rent prices, populations, numbers of new homes, loan interest rates and G.D.P. The approximate study period was 1975–2010 because of the differing availability of data from each country. Hott compared estimated house prices and fundamental rent values with real values. In terms of rent, the gap between the fundamentals and real rent values was small in all countries. By contrast, a huge gap was observed between the fundamentals and real value of house prices regardless of their original sequences and volatility.

Earlier studies, such as the framework by Campbell and Shiller (1988), have divided the price-to-rent ratio into fundamentals and mispricing, with mispricing referring to the mispricing of house prices relative to rent or house price deviation measured in terms of rent (fundamentals). Brunnermeier and Julliard (2008) referenced the method of Campbell and Shiller (1988) and divided price-to-rent ratio into rationality (which can be explained by the fundamentals) and mispricing, using the U.K. housing market from 1966 quarter (Q) 2 to 2004 Q4 as the research subject. Brunnermeier and Julliard discovered that three proxy variables for inflationary bias

had significant explanatory power toward mispricing, thereby explaining the cause of mispricing through money illusion.

In addition to money illusion, some studies have investigated whether other irrational factors cause house price deviation. Lux (1995) believed that herd behaviour has a positive feedback effect on market price and investor sentiment. For example, investors become more optimistic when prices rise and excess returns occur, thereby causing prices to rise further. Hott (2012) included the proxy variable for herd behaviour in the house price model and found that herd behaviour possesses explanatory power over house price deviation. Regardless of whether the impact originates from money illusion, house price deviation is an irrational house price behaviour. The continued existence of irrational factors leads to persisting house price deviation and yields 'momentum'. Moskowitz, Ooi and Pedersen (2012) tested the futures contracts of 58 subjects including stock indices, currencies, raw materials and bonds and discovered momentum in returns on assets. Lai and Van Order (2010) verified that the housing market contains momentum of positive deviation from the fundamentals.

Numerous studies have provided evidence related to whether house price deviation occurs in the European housing market. For example, Zhou and Sornette (2003) discovered that the U.K. housing market was in a bubble and believed that the bubble would likely have an impact on the economy by the end of 2003. Hiebert and Sydow (2011) studied remuneration on house prices in eight eurozone countries (Belgium, Germany, Spain, France, Ireland, Italy, the Netherlands and Finland) and used the V.A.R. model to estimate four variables: excess remuneration on houses, rent, real interest rates and personal income. The studied period was 1978–2009 and samples were collected quarterly. The evidence presented by Hiebert and Sydow indicated that eurozone house prices overreact to news, thereby signifying the existence of irrational house price behaviour. Hiebert and Sydow (2011) investigated the aforementioned eight eurozone countries because they accounted for 90% of the eurozone G.D.P. The U.K. is highly correlated with these countries despite not using the euro, and numerous studies have proven the existence of the aforementioned U.K. housing market bubble. Therefore, the present study investigated the housing markets of the same eight major eurozone countries together with that of the U.K. for analysis.

Some results from previous studies have implied that the various types of disorder in the European housing market may be linked. For example, Ott (2014) discussed European house prices, analysed the key factors affecting house prices, and investigated the housing cycle to predict future house prices. The research sample consisted of the house price indices and relevant overall economic variables of eight European countries from 1970 to 2012. Ott believed that the prosperity of the housing market beginning in the mid-1990s was caused by the following three factors: the emergence of European Union organisations, excess savings and the economic recovery of the period. However, the U.S. subprime mortgage crisis in 2007 caused a global economic recession that resulted in a decline in European people's income level and caused a further collapse in house prices, which only returned to a state of equilibrium in 2014. The present study was more objective than Ott (2014) in its use of a quantitative approach to explain the linkage in European housing market imbalances.

2.2. Housing price deviation and the deterioration of housing affordability

Housing prices are affected by numerous factors. For instance, among the typical variables employed in a housing market demand and supply model (e.g., income, number of households, interest rates, housing stock and construction costs), some are long-term variables and others are short-term. Employing various types of variables in a model to calculate housing price fundamentals leads to different expectations for long-term and short-term housing prices. The present study examined housing price deviations relative to income, a phenomenon indicating disequilibrium in housing affordability. Housing affordability is an indicator of a householder's pressure in purchasing housing. According to Hulchanski (1995), a housing affordability problem refers to an increasing housing expenditure-to-income ratio in households intending to own suitable housing. The irrational inflation of housing prices relative to income results in considerable pressure for households planning to purchase housing.

Therefore, personal disposable income has always been a crucial factor in determining the fundamentals of house prices. Malpezzi (1999) noted that the house price-to-income ratio is a simple measure of whether the housing market is functioning properly. Numerous earlier studies have used the relationship between house prices and income to determine whether countries' housing markets are in disorder and whether the public is overburdened by housing expenses (e.g., Bramley, 1994; Yamada, 1999). Recent studies (e.g., Pavlidis et al., 2016) have determined housing market exuberance based on whether the relationship between house prices and income is integrated (whether the house price-to-income ratio is stationary).

The Federal Reserve Bank of Dallas also used this approach to establish the exuberance indicator to provide information on whether the housing market is overheating and whether the housing market risk is rising. To observe the transfer of international housing market risks when the housing market is overheating and its risk is rising, the deviation of house prices relative to income would first be estimated.

In addition, several previous studies (Brunnermeier & Julliard, 2008; Hayunga & Lung, 2011; Chen, 2016) have discovered that the reason for the house price deviation from the fundamentals originates from mispricing caused by money illusion, these studies have referred to house price deviation as mispricing. The use of a unified currency increases the integration of interest rates across eurozone countries. As a crucial factor affecting housing price demand, interest rates also affect mortgage affordability, thereby influencing decisions to rent or purchase housing. In addition to observing the contagion effects causing disequilibrium in housing prices across countries, this study examined whether inflation rates and interest rates are short-term factors that contribute to such contagion.

2.3. House price correlation between European countries

Vansteenkiste and Hiebert (2011) studied the spillover phenomenon of European house prices and impact of domestic long-term interest rate fluctuations on house prices in seven countries. Their research samples used quarterly house price indices, per capita income and long-term government bond interest rates from seven

European countries. The empirical results indicated a spillover effect among the house prices of the sampled countries; however, the model coefficient revealed this effect to be lowly impactful. The research results for Spain and Ireland revealed an increasingly large impact of domestic long-term interest rates on house prices.

Álvarez et al. (2010) explored the housing cycles of four European countries (France, Spain, Germany and Italy) and compared the G.D.P. cycle of each country to understand the correlation between the housing markets of the four countries. The research samples consisted of nominal and real house price indices, housing and non-housing investment amounts, G.D.P., numbers of construction permits and housing starts of the four European countries from 1980 Q1 to 2008 Q4. Álvarez et al. discovered that G.D.P. had the highest average correlation among the variables, which should indicate a high degree of trade linkage between countries. By contrast, the correlation between residential investment amounts and nominal and real house prices was relatively weak, with each country's housing market status being mainly determined by its economy or regulations.

The results of Vansteenkiste and Hiebert (2011) and Álvarez et al. (2010) have implied a low correlation among eurozone house prices. Even if the studied eurozone countries are highly connected in terms of overall economic aspects and use the same currency, certain properties may still possess the function of risk diversification. However, such a function may not be present during financial crises. For example, De Bandt and Malik (2010) studied the contagious phenomenon of housing markets during the crisis in the U.K. and Spain and discovered that the reactions of house prices to the general impact during the crisis were expanded. Based on data from the global securitized real estate market in 1999–2010, Hoesli and Reka (2013) presented evidence indicating a contagious phenomenon between the U.S. and U.K. after the subprime mortgage crisis. In addition, De Bandt, Barhoumi and Bruneau (2010) provided evidence suggesting that the contagious aspect of U.S. house prices affected house prices in the U.K. and Spain.

Based on the aforementioned studies, the present study argued that a complete assessment of investment risks in the transnational housing market in Europe should measure their correlation level in the case of market imbalances. In addition, a dynamic model should be used for estimation to distinguish between the causes derived from the countries themselves and those derived from the impacts of other countries.

3. Estimation of house price deviation

The real house price index and real personal disposable income index of eight eurozone countries (Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands and Spain) and the U.K. between 1975 Q1 and 2017 Q1 were investigated in this study. The source of house prices and income information was the official website of the Federal Reserve Bank of Dallas. The Globalisation and Monetary Policy Institute of the Federal Reserve Bank of Dallas prepared a house price index for multiple countries similar to how the Federal Housing Finance Agency prepared a quarterly U.S. house price index for existing single-family houses. The house price indices of all the countries were quarterly adjusted, with 2005 being used as the base period.

Table 1. Descriptive statistics of house price index and personal disposable income.

<i>P</i>	Belgium	Finland	France	Germany	Ireland
Mean	77.80	75.02	71.04	108.81	52.03
Maximum	122.33	112.15	115.42	126.79	118.69
Minimum	41.96	44.57	43.2	93.04	23.28
Std. Dev.	27.97	23.16	25.48	8.97	28.85
Skewness	0.49	0.33	0.69	0.11	0.73
Kurtosis	1.74	1.57	1.73	2.48	2.22
<i>P</i>	Italy	Netherlands	Spain	UK	
Mean	77.51	65.99	71.31	60.99	
Maximum	108.07	105.13	109.32	115.03	
Minimum	53.46	33.2	35.74	26.16	
Std. Dev.	15.61	24.58	20.21	29.05	
Skewness	0.25	0.21	0.30	0.46	
Kurtosis	2	1.48	1.86	1.61	
<i>Y</i>	Belgium	Finland	France	Germany	Ireland
Mean	90.02	84.06	87.01	89.07	75.11
Maximum	105.05	116.62	105.91	111.97	117.97
Minimum	66.15	51.54	66.12	65.2	48.84
Std. Dev.	11.66	19.92	13.58	14.18	23.38
Skewness	-0.41	0.11	0.07	-0.13	0.31
Kurtosis	1.49	1.83	1.41	1.65	1.40
<i>Y</i>	Italy	Netherlands	Spain	UK	
Mean	88.89	89.3	85.15	79.96	
Maximum	102.98	105.02	101.20	109.38	
Minimum	61.94	70.24	66.54	46.98	
Std. Dev.	9.90	11.25	11.86	20.8	
Skewness	-0.87	-0.20	-0.16	-0.16	
Kurtosis	2.88	1.53	1.46	1.48	

Notes: *P* denotes the real house price index, and *Y* denotes the real personal disposable income index.

The real personal disposable income index used the purchasing-power-parity-adjusted G.D.P. divided by the working-age population to obtain per capita terms; the base period was also 2005. For more information, see Mack and Martínez-García (2011).¹

Table 1 shows the simple statistics for the house price and income indices. Figure 1 shows the house price index of the nine countries and Figure 2 displays the personal disposable income index. Figure 2 shows that multiple countries (Belgium, France, Germany, Ireland, the Netherlands and Spain) exhibited relatively stagnant economic performance before 1985, after which their output increased substantially. Figure 1 demonstrates that housing market activity in all nine countries remained at approximately the same level, with only Germany experiencing a persistent housing market depression that improved only after 2010. The economic performance of the eurozone countries should be affected by the implementation of a single monetary policy, with individual output displaying a greater fluctuation during the data period. The U.K. was more stable, although its housing market was significantly affected by the U.S. mortgage crisis in 2007.

Table 2 shows the unit root test results for house prices and income and verifies that the house prices and income of all nine countries were $I(1)$ sequences. In other words, the test results of the original data were nonstationary, whereas the results after differencing were stationary. Because the results in Table 2 indicate that the two variables were nonstationary for all countries and of the same order, the cointegration relationship between house prices and income (unbiased long-term relationship) was

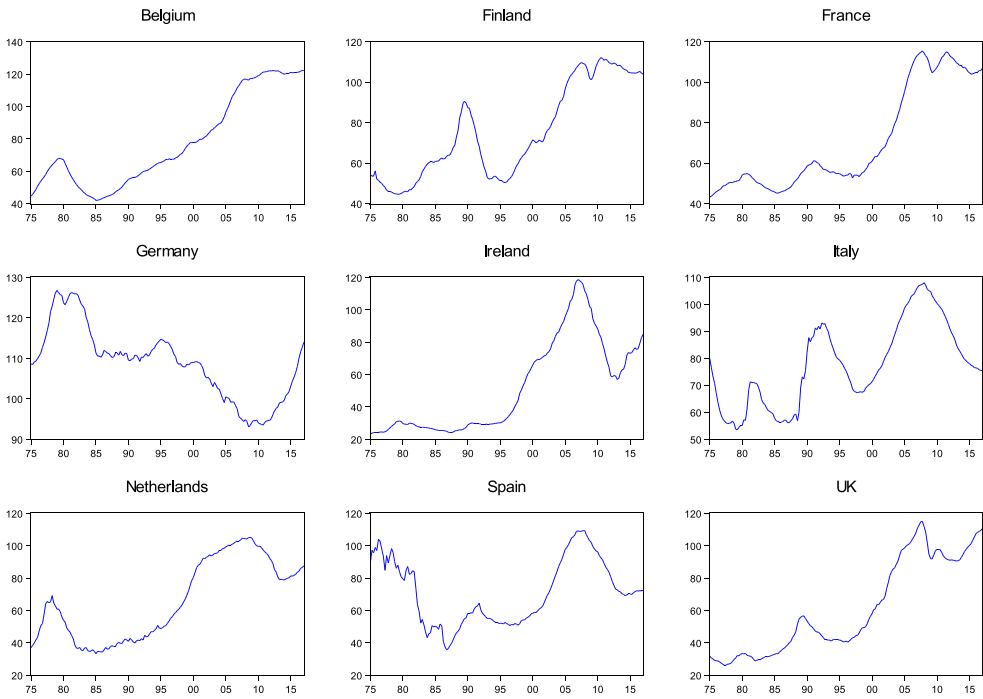


Figure 1. House price index.

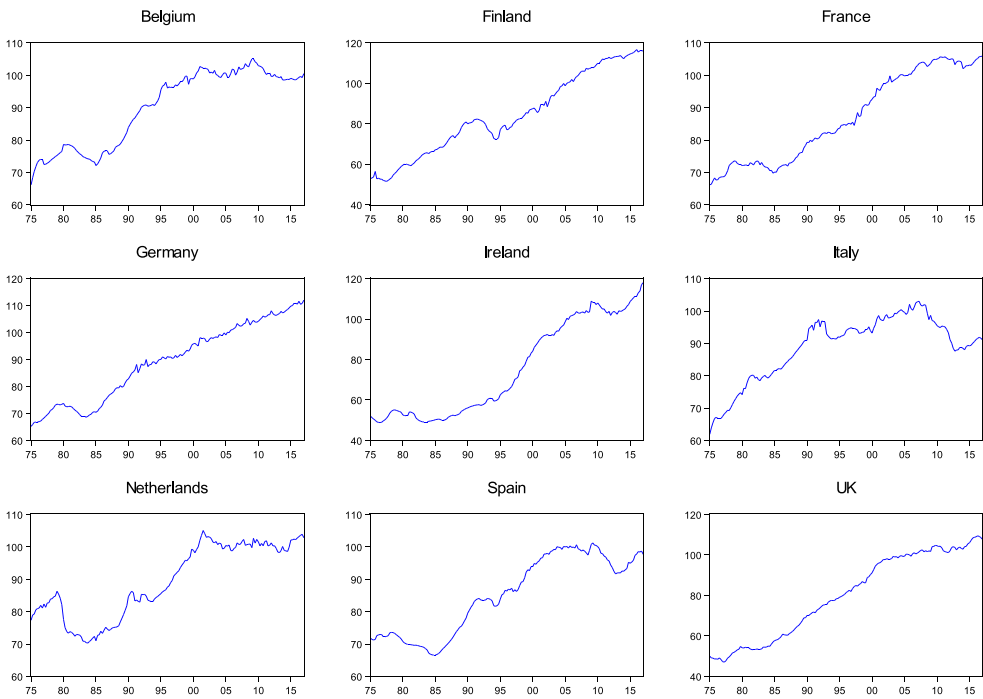


Figure 2. Personal disposable income index.

Table 2. Unit root tests for variables in levels and in differenced form.

<i>P</i>	Belgium	Finland	France	Germany	Ireland
ADF unit root test					
Level	0.92 (0.90)	0.57 (0.84)	1.05 (0.92)	0.14 (0.73)	0.46 (0.81)
First difference	-2.97 (0.00)	-4.91 (0.00)	-3.22 (0.00)	-3.22 (0.00)	-3.19 (0.00)
	Italy	Netherlands	Spain	UK	
Level	0.01 (0.69)	0.12 (0.72)	-1.00 (0.28)	1.09 (0.93)	
First difference	-3.95 (0.00)	-2.25 (0.02)	-9.90 (0.00)	-4.37 (0.00)	
<i>Y</i>					
	Belgium	Finland	France	Germany	Ireland
ADF unit root test					
Level	2.14 (0.99)	4.92 (1.00)	4.52 (1.00)	4.62 (1.00)	2.72 (1.00)
First difference	-9.44 (0.00)	-6.55 (0.00)	-3.97 (0.00)	-2.36 (0.02)	-3.40 (0.00)
	Italy	Netherlands	Spain	UK	
Level	2.01 (0.99)	1.32 (0.95)	1.08 (0.93)	4.48 (1.00)	
First difference	-4.67 (0.00)	-10.25 (0.00)	-4.08 (0.00)	-3.29 (0.00)	

Notes: *P* denotes the real house price index, and *Y* denotes the real personal disposable income index. A.D.F. tests are adopted for testing the null hypothesis of a unit root in the series. The lag length of the unit root models is selected by using the Schwarz information criterion. The entry in parenthesis stands for the *p*-value.

obtained by estimating the fully modified ordinary least squares (F.M.O.L.S.). Increasingly more studies are committed to developing methods that can estimate the relationships between nearly integrated regressors by using fully modified estimation, a commonly used approach that directly uses nonstationary data to explore implied information in long-term relationships. Through F.M.O.L.S. estimation, the long-term equilibrium of house price and income and the reasonable house price and house price deviation estimated using the long-term equilibrium can be obtained.

Table 3 estimates the equilibrium for the house prices of the nine countries. The coefficients (a_1) of the explanatory variables (disposable income) for all countries were significant, indicating that the house prices in these countries change according to disposable income in the long run. House price deviation may exist in the short term, as shown by house price deviation in the nine countries in Fig. 3. Notably, the estimated results in Belgium and Germany indicated the most severe current house price deviation (2016 Q1–2017 Q1), whereas the U.K. was on the verge of returning to the high point of the previous deviation (2007) before correction. Other countries (e.g., Ireland, Netherlands, Italy and Spain) were affected by the U.S. financial crisis, with drastic corrections of house prices in 2007 and 2008. Ireland and the Netherlands have not yet fully recovered, with their house prices still below the reasonable level.

4. Infectivity of house price deviation and momentum effect of the countries own influences

To separate the elements of self-influence and the impact from other countries in relation to house price deviation, this study used the generalised V.A.R. frameworks proposed by Diebold and Yilmaz (2012) based on that by Koop, Pesaran and Potter (1996), and Pesaran and Shin (1998) to calculate the forecast error variance (ω_{ij}). First, the stationary 9-variable V.A.R. model was used to estimate house price deviation. Let the house price deviation of the nine countries be the vector θ_t in the following equation:

Table 3. Estimations for the equilibrium home price (F.M.O.L.S. estimation).

Belgium		Finland		France	
a_0	-90.9797*** (0.0000)	a_0	-16.6109*** (0.0099)	a_0	-76.1843*** (0.0000)
a_1	1.8917*** (0.0000)	a_1	1.0813*** (0.0000)	a_1	1.7144*** (0.0000)
R-squared	0.6505	R-squared	0.8576	R-squared	0.8288
Germany		Ireland		Italy	
a_0	154.5355*** (0.0000)	a_0	-32.1063*** (0.0000)	a_0	-16.1271 (0.2776)
a_1	-0.5036*** (0.0000)	a_1	1.1209*** (0.0000)	a_1	1.0646*** (0.0000)
R-squared	0.6052	R-squared	0.8251	R-squared	0.5549
Netherlands		Spain		UK	
a_0	-116.4640*** (0.0000)	a_0	15.3629 (0.4591)	a_0	-39.0130*** (0.0000)
a_1	2.0533*** (0.0000)	a_1	0.6842*** (0.0050)	a_1	1.2771*** (0.0000)
R-squared	0.8566	R-squared	0.1455	R-squared	0.8310

Notes: This table shows the estimated results of the long-run relationship between home price index and fundamental variables. The estimated model is:

$$P_t^* = a_0 + a_1 Y_t.$$

where P^* denotes the long-run equilibrium real house price index, and Y denotes the real personal disposable income index. *** indicates significance at the 1% level.

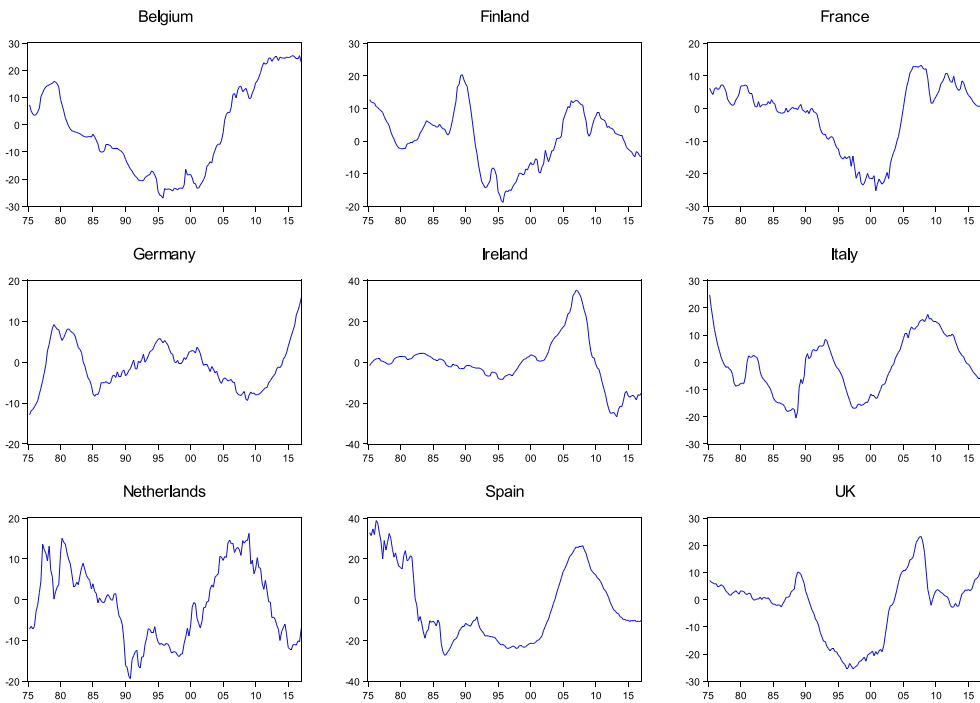


Figure 3. House price Deviation.

$$\theta_t = \sum_{i=1}^{\infty} \delta_i \varepsilon_{t-i} \tag{1}$$

where δ is the coefficient matrix and ε is the residual matrix.

For each deviation i , the shares of its forecast error variance coming from shocks are added to deviation j , where $\forall j \neq i$. The variance decompositions can then be used to assess the fraction of the error variance in forecasting θ_i , which is due to shocks to

Table 4. Interactions between house price deviations.

	Belgium	Finland	France	Germany	Ireland	Italy	Netherlands	Spain	UK
Belgium	85.6	3.4	2.1	1.3	2.2	0.1	0.3	0	5
Finland	3.3	67.6	1.8	1.8	4	0.7	4.9	0.4	15.7
France	3.6	3.2	66.1	2.8	4.5	0.5	6.8	1.2	11.4
Germany	0.2	0.9	4.6	85.5	2.8	0.9	3.8	0.3	0.8
Ireland	1.5	4.5	1.8	0.4	69.1	1.2	0.2	3.8	17.4
Italy	0.7	0.2	0.4	0.3	0.7	95.5	1.4	0.4	0.5
Netherlands	0.1	0.2	4.4	2.7	2.1	3.2	81.9	1.3	4.1
Spain	0	0.5	0.5	0.4	3.3	0.4	0.5	89	5.4
UK	3.9	7.6	1.8	0.7	12.2	1.6	2.4	1.4	68.5

Notes: This table shows the percentage of house price deviation changes in Country j that can be explained by Country i . Each number in the table represents the effects of the vertical countries on their corresponding horizontal countries.

deviation θ_j , where $\forall j \neq i$ for each i . Diebold and Yilmaz proposed the H -step-ahead forecast error variance for $H = 1, 2, \dots$ by using the expression:

$$\omega_{ij(H)} = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e'_i \delta_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e'_i \delta_h \sum \delta'_h e_j)} \tag{2}$$

where \sum is the variance matrix for the error vector ε , σ_{jj} is the standard deviation of the error term for the j th equation, and e_i is the selection vector with 1 as the i th element and 0 otherwise.

Following Diebold and Yilmaz (2012), this article estimated 10-step-ahead forecast error variance, the forecast error variance (ω_{ij}) was obtained and represented the impact of the influence from Country i on the house price deviation in Country j . In addition, each entry of the variance decomposition matrix is normalised by the row sum in order to calculate the spillover index.

Selecting one country and calculating its net impact in relation to the other eight countries quantified that country’s net contagious effect toward the housing markets in the other countries. This effect was regarded as the quantitative measure of the level of infection, expressed as follows:

$$inf_i = \sum_{j=1, i \neq j}^8 \omega_{ij} - \sum_{j=1, i \neq j}^8 \omega_{ji} \tag{3}$$

The impact of Country i on its own house price deviation was defined as the self-influence of house price deviation:

$$Self_i = \omega_{ii} \tag{4}$$

Table 4 shows the interactions between house price deviations, or in other words, the percentage of house price deviation changes in Country j (ω_{ij}) that can be explained by Country i . Each number in the table represents the effects of the vertical countries on their corresponding horizontal countries. According to Table 4, the U.K. exerted the greatest impact with a total explanatory power of 60% over the other countries. The U.K.’s impacts on Finland, France and Ireland were the greatest,

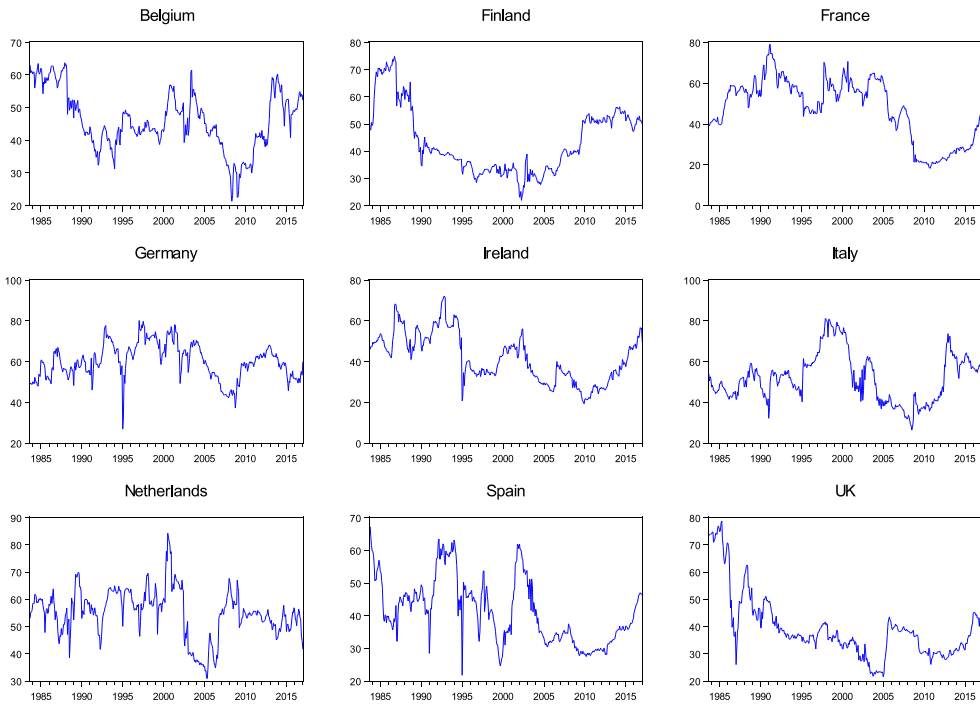


Figure 4. The components of self-influence.

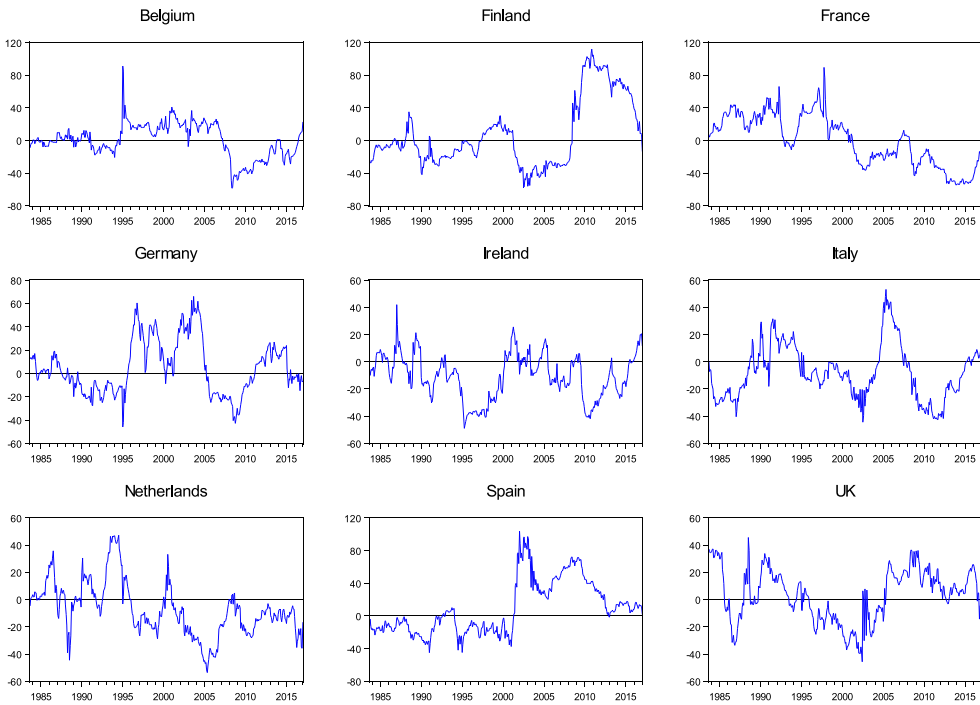


Figure 5. Infectivity.

Table 5. Infectivity and inflation rate.

	Belgium	Finland	France	Germany	Ireland
π	-1.51 (0.03)	-3.58 (0.00)	6.53 (0.00)	-6.22 (0.00)	2.10 (0.00)
Constant	3.45 (0.07)	16.48 (0.00)	-13.85 (0.00)	15.77 (0.00)	-16.29 (0.00)
	Italy	Netherlands	Spain	UK	
π	-0.38 (0.31)	3.90 (0.00)	-4.80 (0.00)	4.97 (0.00)	
Constant	-6.55 (0.00)	-14.63 (0.00)	28.39 (0.00)	-10.48 (0.00)	

Notes: This table shows the estimation results for the relationship between each country's infectivity and domestic inflation rate. The dependent variable is each country's impact capacity on house price deviation in other countries, and independent variable (π) is the inflation rate. The entry in parenthesis stands for the p -value.

Table 6. Momentum effect and inflation rate.

	Belgium	Finland	France	Germany	Ireland
π	0.51 (0.10)	2.23 (0.00)	1.55 (0.00)	0.17 (0.64)	1.69 (0.00)
Constant	44.87 (0.00)	37.97 (0.00)	44.15 (0.00)	59.68 (0.00)	37.17 (0.00)
	Italy	Netherlands	Spain	UK	
π	-0.78 (0.00)	2.37 (0.00)	1.61 (0.00)	3.26 (0.00)	
Constant	54.58 (0.00)	50.56 (0.00)	35.09 (0.00)	30.13 (0.00)	

Notes: This table estimates the proportion of house price deviation affected by the domestic housing market, or in other words, the correlation between the persistence of house price deviation caused by the momentum effect and domestic inflation rate. π denotes the inflation rate. The entry in parenthesis stands for the p -value.

causing error variances in forecasting of 17.4%, 15.7% and 11.4% in Ireland, Finland and France, respectively. France was most affected by other countries, whereas Italy was the least affected (4.5%) and had the smallest impact on other countries (9%). Thus, the house price deviation in Italy was the most irrelevant to the other markets.

The diagonal numbers in Table 4, represent the part where house price deviation was subjected to self-influence (ω_{ii}). When these numbers accounted for a higher proportion and persistent house price deviation occurred, momentum could have been the main contributing reason. In Italy's house price deviation, 95.5% of the changes were self-influenced. This high score in Italy was followed by those of Spain (89%), Belgium (85.6%), Germany (85.5%) and the Netherlands (81.9%), all of which were subjected to higher proportions of self-influence. Compared with the information in Figure 3, Belgium and Germany have shown continued house price deviation since 2010 and the irrational increase in house prices was attributed to momentum as opposed to influence from other markets. Because of the low infectivity of Belgium and Germany on the other markets, with explanatory power of 13% and 10% toward the house price deviation in other markets, respectively, the current deviation in these two markets did not spread to the other eurozone countries.

The results in Table 4 are the estimation results for the samples. Through rolling data estimation, sampling intervals of 100 samples were selected to estimate the dynamic infectivity (inf_i) and self-influence of house price deviation ($Self_i$). Figures 4 and 5 illustrate the self-influence and infectivity of house price deviation, respectively. Similar to the results of Table 4, some countries had a relatively high proportion of self-influence (Italy), whereas some had lower levels of self-influence (U.K.); however, the results in Figure 4 are more capable of showing changes in self-influence over time than are those in Table 4. Figure 4 shows that the U.K.'s self-influence has dropped drastically since the period approaching 1990, during which its

Table 7. Infectivity of Germany.

	Belgium	Finland	France	Ireland
π_G	-2.13 (0.00)	-0.28 (0.43)	-0.10 (0.65)	-1.47 (0.00)
Constant	2.29 (0.00)	3.15 (0.00)	-1.22 (0.01)	5.12 (0.00)
	Italy	Netherlands	Spain	UK
π_G	-0.57 (0.00)	-0.58 (0.00)	0.71 (0.01)	-1.81 (0.00)
Constant	2.41 (0.00)	2.00 (0.00)	-4.35 (0.00)	6.38 (0.00)

Notes: This table shows the relationship between the net infecting effect from Germany and the inflation rate of Germany. π_G denotes the inflation rate of Germany. The entry in parenthesis stands for the p -value.

Table 8. Infectivity of the U.K.

	Belgium	Finland	France	Germany
π_{UK}	0.55 (0.00)	4.00 (0.00)	0.97 (0.00)	0.44 (0.00)
Constant	-1.58 (0.00)	-13.00 (0.00)	2.97 (0.00)	-4.40 (0.00)
	Ireland	Italy	Netherlands	Spain
π_{UK}	0.35 (0.04)	-2.29 (0.00)	-0.44 (0.01)	1.40 (0.00)
Constant	0.29 (0.61)	7.00 (0.00)	0.23 (0.67)	-2.00 (0.01)

Notes: This table shows the relationship between the net infecting effect from the U.K. and the inflation rate of the U.K. π_{UK} denotes the inflation rate of the U.K.. The entry in parenthesis stands for the p -value.

proportion of self-influence did not exceed 50%, thereby indicating a high connection between the U.K. and the eurozone countries. Most of the eurozone housing markets have displayed a decline in connection (increased self-influence) since 2010, likely because of the impacts of the U.S. and U.K.'s financial crisis between 2005 and 2010, during which time the level of infection between housing markets peaked.

With a control line using 0 to indicate the net contagious effect, [Figure 5](#) evidently shows when a country had a greater contagious effect on the other countries and when the effects of other countries were stronger. The infectivity trends of Spain and France were in contrast to each other; before 2001, Spain's housing market was more oriented toward an infected market with France having a mostly positive infectivity. However, after 2001, Spain's infectivity was mostly positive and more inclined toward a highly contagious market, whereas France's housing market was more oriented toward an infected market. Previous studies ([De Bandt & Malik, 2010](#)) have discovered the presence of the contagious effect in Spain's housing market, possibly capturing the unstable state of Spain's housing market after 2001.

Regarding the reasons for the momentum of the continued house price deviation, previous studies have asserted that money illusion causes house price deviation ([Brunnermeier & Julliard, 2008](#)), which in turn affects traders' expectations, results in their continued optimism regarding the performance of house prices, and leads to persistent house price deviation ([Hott, 2012](#)). The present study further verified the two components of house price deviation, namely the influence of housing markets in other countries and self-influence, and whether money illusion is one of the contributing causes.

[Table 5](#) shows the estimation results for the correlation between each country's impact capacity on house price deviation in other countries (inf_i) and domestic inflation rate.² The results indicate that apart from Italy, each country's infection capacity in terms of housing markets in other countries was significantly affected by its own level of inflation. Because Italy's house price deviation was the least relevant to the other markets, this result was reasonable. However, the estimated results for

Table 9. Infectivity and interest rate.

	Belgium	Finland	France	Germany	Ireland
$i_{euro} - i_d$	1.42 (0.11)	8.00 (0.00)	-5.89 (0.00)	1.10 (0.10)	-1.85 (0.00)
Constant	-2.25 (0.20)	1.61 (0.49)	8.40 (0.00)	1.85 (0.38)	-9.26 (0.00)
	Italy	Netherlands	Spain	UK	
$i_{euro} - i_d$	-0.99 (0.01)	1.66 (0.05)	5.75 (0.00)	1.08 (0.02)	
Constant	-8.04 (0.00)	-11.52 (0.00)	11.16 (0.00)	3.23 (0.00)	

Notes: This table shows the estimation results for the relationship between each country's infectivity and domestic interest rate. The dependent variable is each country's impact capacity on house price deviation in other countries, and independent variable ($i_{euro} - i_d$) is the relative interest rate. The entry in parenthesis stands for the p -value.

Table 10. Momentum effect and interest rate.

	Belgium	Finland	France	Germany	Ireland
$i_{euro} - i_d$	0.47 (0.22)	-0.44 (0.08)	-5.63 (0.00)	-0.83 (0.00)	-2.36 (0.00)
Constant	45.30 (0.00)	41.49 (0.00)	55.23 (0.00)	62.13 (0.00)	43.31 (0.00)
	Italy	Netherlands	Spain	UK	
$i_{euro} - i_d$	0.22 (0.37)	-0.26 (0.50)	-1.91 (0.00)	-1.27 (0.00)	
Constant	51.89 (0.00)	55.39 (0.00)	40.88 (0.00)	39.48 (0.00)	

Notes: This table estimates the proportion of house price deviation affected by the domestic housing market, or in other words, the correlation between the persistence of house price deviation caused by the momentum effect and domestic interest rate. Independent variable ($i_{euro} - i_d$) is the relative interest rate. The entry in parenthesis stands for the p -value.

Belgium, Finland, Germany and Spain indicated that a rise in a country's inflation rate can lead to a decline in that country's capacity to infect other countries' house price deviation. A possible reason for this was the persistence of house price deviation in these countries and its main contributing factor was each country's own level of momentum (Table 4), which was related to money illusion. Therefore, an increase in the inflation rate mainly affected the variance that could be explained by the countries themselves, or in other words, a momentum effect was more likely to be formed, resulting in a decline in each country's level of connection with the other countries.

Table 6 estimates the proportion of house price deviation affected by the domestic housing market (ω_{ii}), or in other words, the correlation between the persistence of house price deviation caused by the momentum effect and domestic inflation rate. The results show that apart from Italy, each country's house price deviations were significantly and positively affected by the inflation rate. Therefore, a higher domestic inflation rate indicated that the domestic mispricing of house prices was more likely to be caused by money illusion than by influence from other countries. Thus, if persistent house price deviation occurred at the time, its major contributing cause was the momentum effect. The results in Tables 5 and 6 illustrate that a higher price growth rate in the U.K. increased its infection capacity toward other markets as well as the likelihood of forming the momentum effect for house price deviation. Coupled with Table 4 showing that the U.K.'s house price deviation had the highest connection with other markets, the evidence demonstrated that a high rate of inflation in the U.K. could easily result in imbalances in the eurozone housing markets. Apart from the U.K., the countries in this study use the euro and have a single monetary policy. To further explain the essentialness of the impact of the U.K.'s monetary policy on the eurozone countries, this study examined whether the inflation rate in the U.K. determined the net impact of the U.K. on the other markets.

Therefore, the net impact of the U.K. on other markets was used in this study and is expressed as follows:

$$inf_{UK,j} = \omega_{UK,j} - \omega_{j,UK} \quad (5)$$

where j represents the eight eurozone countries.

The net impact of Germany on the other countries was also used for comparison and is expressed as follows:

$$inf_{G,j} = \omega_{G,j} - \omega_{j,G} \quad (6)$$

where j represents the eight countries in this study excluding Germany.

Tables 7 and 8 show the estimation results for whether the net impacts of Germany and the U.K. on the other markets were related to their respective inflation rates. Table 7 shows that the higher inflation rate in Germany did not increase the net contagious effect on other markets and reduced its net impact on the other markets, with the exception of Spain, where the high inflation rate increased the net impact on house price deviation.

Table 8 illustrates the essentialness of the U.K.'s monetary policy and inflation rate in relation to the housing markets in the eurozone countries. Apart from Italy and the Netherlands, where house price deviations were more susceptible to self-influence, a higher inflation rate in the U.K. significantly enhanced the U.K.'s net contagious effect on the other markets. From the estimation results of the eurozone markets, excessive monetary easing in the U.K. led to a higher inflation rate, which became a significant factor affecting the housing market imbalances in the eurozone countries. In addition, De Bandt and Malik (2010) and De Bandt et al. (2010) presented evidence indicating the presence of a contagious effect in the housing markets of the U.K. and Spain during the financial crisis. The present study discovered that Spain's house price deviation was susceptible to impact from the inflation rates in Germany and the U.K., a result that was consistent with those of previous studies that have proposed that Spain's housing market is prone to exerting contagious effects.

After examining the 17 largest cities in Poland during the 2002–2015 periods, Leszczyński and Olszewski (2017) revealed that housing prices in the secondary market were more affected by economic fundamentals, particularly real interest rates, than were those in the primary market. This may be because buyers in the secondary market owned little capital and thus required a higher mortgage. Moreover, owner-occupied housing was less likely to be affected by speculative demand. By analysing data from the Organisation for Economic Cooperation and Development countries, Andrews and Sánchez (2011) found that the increase in the number owner-occupied housing was subject to not only demographic factors within these countries, but also mortgage interest. After reviewing the aforementioned studies, the present study examined whether the interest rate serves as the primary factor affecting contagion effects across housing markets.

Table 9 displays the results of investigating whether the ability of a country to influence housing price deviation in other countries (inf_i) is determined by its low interest rate.³ The relative interest rate of each country was calculated by deducting

its interest rate from the average interest rate of the eurozone, after which it was used as the independent variable in Tables 9 and 10. The result revealed that, except for Belgium and Germany, the ability of all countries to affect the housing markets in other countries (i.e., the contagion effect) was significantly affected by the relative interest rate. Table 10 presents the correlation between the degree of housing price deviation (ω_{ii}), which is subject to changes in a country's housing market, and the relative interest rate in the sample countries. The result revealed that, except for Belgium, Finland, Italy and the Netherlands, housing price deviation in the remaining countries were significantly influenced by the relative interest rates. Furthermore, higher interest rates in a country led to a higher domestic influence, implying that the housing price deviation in a country is more likely determined by the domestic interest rate than by housing markets in other countries. Conversely, the main reason for housing price deviation during a period of low interest rates is due to influences from the housing markets in other countries. In conclusion, the result presented in Table 9 suggests that the interest rate affects the connectivity between the housing market in a country and the housing markets in other countries. Table 10 shows that higher domestic interest rates contribute to a higher domestic influence on housing price deviation.

5. Conclusion

In this study, the real house price index and real personal disposable income index from eight eurozone countries (Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands and Spain) and the U.K. between 1975 Q1 and 2017 Q1 were investigated. This study explored whether irrational behaviours exist in relation to the house prices in European countries; whether the deviation of house prices from fundamentals (unreasonable house price fluctuations) is mutually contagious or whether house price deviation is self-correcting; which countries infect other countries through domestic house price deviation; and which countries' house price deviations are susceptible to domestic factors. Finally, this study explored the main factors of the contagiousness of house price deviation and self-influence.

First, this study estimated the cointegration relationship between house prices and income (unbiased long-term relationship) to determine the long-term equilibrium for house prices and income and the reasonable house price and house price deviation inferred from this relationship. To disassemble the components of self-influence and impact from other countries from house price deviation, this study used the method proposed by Diebold and Yilmaz (2012) to calculate the forecast error variance and further estimated the interaction of house price deviation within all the sample periods. The U.K. had the greatest impact on the other regions, whereas France was the most affected by the other countries. Italy was the least affected by the other countries and also had the least impact on other regions. With a 95.5% change in house price deviation, Italy was susceptible to its own changes, and thus Italy's house prices were the least relevant to the other markets.

This study estimated the correlation between each country's impact capacity on house price deviation in other countries and the domestic inflation rate. The results

indicated that apart from Italy, each country's infection capacity on the housing markets in the other countries was significantly affected by the domestic inflation level. In addition, regarding the estimation of the correlation between the proportion of house price deviation affected by the domestic housing market and domestic inflation rate, the results indicated that apart from Italy, the self-influence of house price deviation was significantly and positively affected by the inflation rate. Therefore, a higher domestic inflation rate indicated that the domestic mispricing of house prices was more likely the result of money illusion as opposed to influence from other countries, and thus the major contributing cause of persistent house price deviation was the momentum effect.

Finally, this study discovered that a higher price growth rate in the U.K. increased the U.K.'s infection capacity toward the other markets and the likelihood of the momentum effect being formed for house price deviation, hence the essentialness of the U.K.'s monetary policy and inflation rate in relation to the housing markets in the eurozone countries. Moreover, this study found that low interest rates reduced the influence of domestic factors on housing price deviation, thereby leading to higher contagion effects from other countries.

Brunnermeier and Julliard (2008) attributed housing price deviation to a money illusion. The empirical results of the present study provided evidence for the presence of a money illusion in housing markets across countries. The results also confirm those of De Bandt and Malik (2010) and De Bandt et al. (2010), who revealed evidence of contagion effects in Spain. This study further illustrated that the housing deviation in Spain was driven by the inflation rates in Germany and the U.K.

This study provided an approach for discussing the risks associated with housing markets by observing infectivity and self-influence in house price deviation. This approach can quantify and objectively analyse the systemic risks of regional housing markets and explain the factors that affect these risks. Eight eurozone countries and the U.K. were used as the study sample to illustrate that although the U.K. does not use the euro, its inflation rate causes infection that leads to imbalance in eurozone housing markets, thereby demonstrating the impact of the U.K.'s monetary policy on eurozone housing markets.

Notes

1. The authors acknowledge use of the data set described in Mack and Martínez-García (2011).
2. Source: National sources, B.I.S. Consumer price series (<http://www.bis.org/statistics/cp.htm>).
3. Source: O.E.C.D. data (<https://data.oecd.org/interest/short-term-interest-rates.htm>).

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