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Volatility Transmission Between Housing and Stock Markets In Europe: A Multivariate Garch Perspective

Avrupa Gayrimenkul Ve Hisse Senedi Piyasaları Arasındaki Oynaklık Yayılımı: Çok Değişkenli Garch Yaklaşımı

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Abstract

Over the past decade, the significant changes in the prices of stock and real estate markets have intensified the interest of heightened concern about volatility in these markets. This paper deals with the dynamic return and volatility transmissions across real estate and stock markets in European countries over the period from 1985:Q1 through 2017:Q1. Using VAR-BEKK-GARCH model, we find significant evidence supporting shock and volatility spillover effects from real estate to stock markets in Denmark, Finland, Ireland and Spain whereas evidence running from stock to real estate markets is found in Spain, Sweden and Italy. In contrast, there is no evidence of any such spillovers in Belgium. Overall, these empirical findings provide fresh insights and policy implications in cross-market volatility spillovers for domestic and international investors, and also policy makers, through the potential for improved risk management and more efficient portfolio diversification.

Keywords

Real Estate Markets • Stock Markets • Volatility Spillover • Multivariate GARCH

JEL Codes

C5 • G11 • G15 • F3

Öz

Son yıllarda, hisse senedi ve gayrimenkul piyasasındaki fiyatlarda meydana gelen önemli değişiklikler, bu piyasalarda oynaklığın artmasına neden olmuştur. Bu makale, 1985-2007 yılları arasında Avrupa ülkelerindeki gayrimenkul ve hisse senedi piyasalarındaki dinamik getiri ve oynaklık yayılımını VAR-BEKK-GARCH modeli kullanılarak araştırmaktadır. Makalede, Danimarka, Finlandiya, İrlanda ve İspanya'da gayrimenkul piyasalarından hisse senedi piyasalarına şok ve oynaklık yayılım etkileri tespit edilmiştir. İspanya, İsveç ve İtalya'da ise hisse senedi piyasalarından gayrimenkul piyasalarına doğru bir oynaklık yayılımının söz konusu olduğu gözlenmektedir. Buna karşın, Belçika'da hisse senedi ve gayrimenkul piyasaları arasında herhangi bir yayılma olduğuna dair bir kanıt bulunmamaktadır. Genel olarak, bu ampirik bulgular, gelişmiş risk yönetimi ve daha etkin portföy çeşitlendirme potansiyeli sayesinde yerli ve yabancı yatırımcılar ile politika yapıcılar için piyasalar arası oynaklık yayılmalarında yeni anlayışlar ortaya koymaktadır.

Anahtar Kelimeler

Gayrimenkul Piyasaları • Hisse senedi Piyasaları • Oynaklık Yayılımı • Çok Değişkenli GARCH Modeli

JEL Kodları

C5 • G11 • G15 • F3

Since the last two decades, financial markets have become more volatile with the wave of financial liberalization and globalization. With the rapid development of globalization, significant increase in cross-border financial activity and dramatic progress in trading technology, financial markets have become more and more closely correlated, leading to faster information transmission. It is therefore of fundamental significance to understand time-varying volatility and volatility transmission mechanism across different types of markets for professionals including international investors, portfolio managers and policy makers. This understanding has the potential to sheds more light on the information transmission process from one market to another for both micro (asset valuation and riskmanagement) and macro (economic policy and risk management) agents. Therefore, the analysis of the market

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volatility spillovers has generated increasing interest.

The real estate and stock markets are considered as market alternatives for investors, and therefore the liquidity and the linkage between these markets have drawn the attention of investors in the recent years. Even though the characteristics of the stock and real estate differ, their values are affected strongly by the same economic conditions, such as inflation, interest rate, economic development, financial crises, and so on. Some researchers have argued that institutional investors get diversification benefits from real estate due to its low correlation with commonly used stock price indices (Quan and Titman, 1999). However, not all researchers agree, and several explanations have been proposed to enlighten the potential dynamic interaction between house and stock prices (Kapopoulos and Siokis 2005; Piazzesi et al. 2007).

The main purpose of this paper is to analyze empirically the volatility linkages among twelve selected European countries utilizing stock and real estate indices from 1985 through 2017. The data period for this study covers unprecedented turbulent times, witnessing many fiscal and monetary policy decisions in the European Union after the intensification of the economic and financial crisis, which heightened uncertainty in all investment markets, including real estate. Specifically, the 2008 subprime mortgage crisis, spread from the US to many countries, continues to have a considerable effect on both real estate and stock markets in the twelve European countries surveyed, as represented in Figure 1. This figure indicates that the effects of these conditions on these assets differ by countries. Thus, the integrated relationship between these markets in all European countries through the return and volatility transmission process have attracted attention from investors, academicians and policy makers, as well as householders.

The Vector Autoregressive-Multivariate Generalized Autoregressive Conditional Heteroskedasticity model (VAR-BEKK-GARCH) is applied to explore temporal volatility spillovers of stock and real estate markets in 12 developed European countries; Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherland, Spain, Sweden, Switzerland and the UK. The BEKK model specification allows to study the possible transmission of volatility from one market to another without parameters restrictions to assure the positivity of the conditional covariance matrix. Further, Vector Autoregression (VAR) lags method is employed to capture return spillover and the interdependence of one market on another. The main findings indicate that, in terms of mean spillover effects, there is a uni-directional spillover in mean from real estate to stock markets in Belgium, Denmark, Netherland and Sweden, whereas the reverse direction of spillover effect is only observed in Switzerland. Interestingly, bidirectional spillover effect is evident only in the case of Italy. Turning to the volatility spillover results, among all the European countries, only Belgium and France experience no shock and volatility spillover effects between these two markets. For the other European countries, there exists more or less uni-directional and/or bi-directional spillovers between real estate and stock markets.

The contribution of this paper to the related literature is threefold. First, although there has been increasing interest in modeling the mean and volatility spillovers across different financial markets, to our best knowledge, surprisingly little research focuses both on real estate and stock markets in developed European economies. Second, the extant research primarily concentrates on investigating the cointegration between stock and real estate markets, while there is a paucity of empirical evidence for volatility spillover between real estate and stock markets in an international context. Therefore, this paper provides a comprehensive examination of volatility spillovers between these markets in major European countries. Finally, this paper extends the analysis of time varying volatility spillover by using a multivariate GARCH (M-GARCH) framework, considered ideal for modeling volatility transmission and understanding the comovements of financial returns.

The remainder of this paper is organized as follows: Section 2 reviews the related literature. Section 3 introduces the data descriptions and econometric methodology. Section 4 presents the empirical results and discussions. Finally, Section 5 contains concluding remarks.

Literature Review

An emerging strand of the literature focuses on the relationship between stock and real estate markets, and a number of studies consider whether the real estate and stock markets exhibit segmentation or integration. Although the cointegrating relationship between stocks and real estate markets has been extensively examined, the extent to which these two markets interact is not clear. On one hand, there is a widespread evidence, supporting the notion that the stock and real estate markets exhibit segmentation (Schnare and Struyk (1976), Goodman (1978, 1981), Grissom et al. (1987), Kuhle (1987), Geltner (1990, 1991), Miles et al. (1990), Liu et al. (1990), Wilson and Okunev (1996) and Lu et al. (2007)). On the other hand, evidence of integration between these markets is provided by Ambrose et al. (1992), Gyourko and Keim (1992), Wilson et al. (1996), Okunev and Wilson (1997), Chaudhry et al. (1999), Wilson and Okunev (1999), Fraser et al. (2002), Liow and Yang (2005), Liow (2006); Apergis and Lambrinidis (2011), Tsai et al. (2012), Lin and Fuerst (2014).

A number of recent papers have also extended the analysis of causal interactions between real estate and stock markets by applying Granger causality tests in vector autoregressive (VAR), vector error-correction (VEC), and threshold error-correction (TEC) models (Gyourko and Keim (1992); McMillan (2012); Okunev et al. (2000); Chen (2001), Sutton (2002), Kakes and Van Den End (2004), Sim and Chang (2006); Ibrahim (2010); Su (2011); Su et al. (2011); Tsai et al., 2012, Lean and Smyth (2012), Shirvani et al. (2012); Anderson and Beracha (2012).

Recently, there has been an increase in the number and robustness of studies on how to model volatility spillovers across different types of assets or across international markets. Stock markets and real estate markets are essential parts of the capital markets; thus, studies on how to explore the volatility spillovers between these markets are vital in risk management, asset pricing and portfolio selection. However, far less formal attention has been devoted to the issue of volatility spillover research between real estate and stock markets in the literature. It is notable that the Vector Autoregressive-Multivariate Generalized Autoregressive Conditional Heteroskedasticity models (VAR-MGARCH) have been commonly used in studies investigating the temporal volatility spillovers between financial markets. Cotter and Stevenson (2006) examined the conditional volatilities and correlations in the US REIT and equity return series utilizing a multivariate VAR-GARCH model. Employing an asymmetric covariance GARCH model, Michayluk et al. (2006) investigated volatility spillover effect and time-varying correlation dynamics between the US and UK real estate markets. Liow et al. (2009) deployed DCC methodology to assess the correlation and volatility dynamics in five developed, real estate securities and stock markets: the US, UK, Japan, Hong Kong, and Singapore.

As this review shows, there is little evidence in the extant literature on the volatility spillover effects among real estate and stock markets. Due to the importance of the real estate and stock markets after the intensification of the economic and financial crisis in European countries, our empirical analysis focuses on the shock and volatility transmission between these markets in this region.

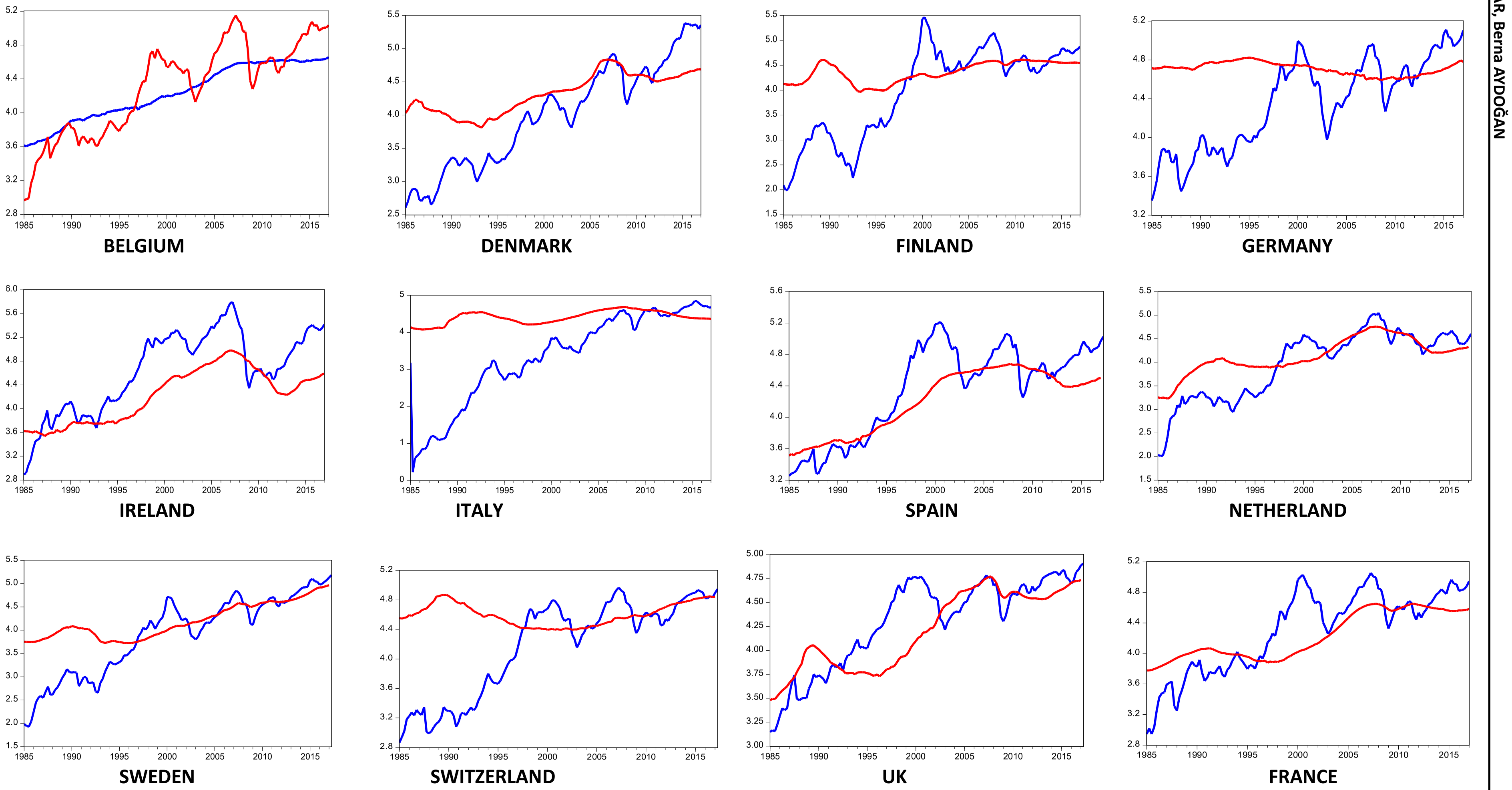
Data

The data used in this study consists of quarterly observations on the natural logarithm of the housing price indices and the natural logarithm of stock prices from the first quarter of 1985 until 2017. The sample covers for 12 European countries, namely, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherland, Spain, Sweden, Switzerland, and the UK. The quarterly indices for real house prices and stock prices were obtained from the OECD database.

The data collected covers the subprime mortgage crisis of 2008. As shown in Figure 1, this subprime crisis had a direct effect on housing prices in these European countries. Due to the limited data set for housing price indices, especially after the 2008 mortgage crisis, it is not currently possible to investigate the relationship between stock and housing market indices by dividing the whole sample period into pre-crisis and post-crisis periods, such an analysis may be possible in the future when more data accumulates.

Table 1 presents the selected descriptive statistics for the stock returns and real housing price returns, revealing that the sample mean for all returns are positive. All return distributions are negatively skewed with the exceptions of Italy, Switzerland, the UK's real estate market indices, and both Spain's real estate and stock market indices. According to the standard deviations, the stock markets have a greater volatility than the real estate markets. All the skewness coefficients are not equal to zero, and all the kurtosis statistics are greater than 3, indicating that the series tend to follow a leptokurtic distribution with higher peaks and fatter tails. The values of the coefficients of skewness, kurtosis together with the large Jarque-Bera.

Figure 1: *European Real Estate and Stock Price Indices*



Note: The blue line pattern represents stock return. The red line pattern represents real housing price return.

(J-B) statistics lead to the rejection of the null hypothesis of a normal distribution, which means that all series are not normally distributed.

Table 1: *Descriptive Statistics*

	Mean (%)	Min. (%)	Max. (%)	Std. Dev. (%)	Skewness	Excess Kurtosis	*JB*
Panel A: European Real Estate Markets							
Belgium	0.016	-0.370	0.183	0.079	-1.413	7.338	142.97*
Denmark	0.005	-0.088	0.075	0.024	-0.221	5.182	26.441*
Finland	0.003	-0.078	0.094	0.026	-0.008	5.176	25.272*
France	0.006	-0.027	0.034	0.013	-0.099	4.389	22.204*
Germany	0.0005	-0.052	0.024	0.010	-0.887	6.946	99.862*
Ireland	0.007	-0.071	0.066	0.028	-0.495	2.990	5.239***
Italy	0.001	-0.033	0.107	0.019	1.795	9.908	323.33*
Netherland	0.007	-0.048	0.063	0.016	-0.202	4.328	10.294*
Spain	0.008	-0.059	0.108	0.027	0.117	4.701	6.629**
Sweden	0.009	-0.071	0.044	0.020	-1.335	5.599	74.072*
Switzerland	0.002	-0.036	0.060	0.015	0.181	4.325	10.072*
the UK	0.009	-0.066	0.100	0.024	0.0006	4.500	12.003*
Panel B: European Stock Markets							
Belgium	0.008	-0.038	0.037	0.011	-0.227	3.938	5.806**
Denmark	0.021	-0.394	0.153	0.081	-1.420	7.142	134.54*
Finland	0.021	-0.348	0.415	0.123	-0.319	3.826	5.849**
France	0.016	-0.325	0.217	0.087	-0.896	4.772	33.923*
Germany	0.013	-0.318	0.230	0.089	-0.912	4.533	30.291*
Ireland	0.019	-0.491	0.230	0.100	-1.479	7.988	179.39*
Italy	0.011	-2.96	0.385	0.280	-9.234	98.166	50121*
Netherland	0.013	-0.418	0.162	0.084	-1.870	9.107	273.58*
Spain	0.019	-0.234	0.355	0.096	0.121	4.938	5.018***
Sweden	0.024	-0.290	0.291	0.096	-0.699	4.275	19.124*
Switzerland	0.016	-0.337	0.161	0.076	-1.255	6.248	89.889*
the UK	0.013	-0.246	0.154	0.061	-1.235	6.507	99.462*

Table 2 exhibits the Augmented Dickey–Fuller (ADF) unit root test results for the level and first difference of real estate indices and stock market indices. All series are I(1), indicating that they are stationary after the first difference.

Additionally, the results of ARCH-LM test by Engle (1982) displays that the ARCH effects are statistically significantly in all the return series, which justifies the GARCH-based approach for investigating the return and volatility transmission among the real estate and stock markets.

Table 2: *The unit root and ARCH-LM tests for European stock markets and real estate markets (level and first difference, 1985Q1-2017Q1)*

	Lag Length		**ADF test**		**ARCH LM Test**	
					F-stat	LM-Stat
Country	Level Data	First Difference	Level Data	First Difference		
Belgium	1	0	-3.078	-7.910*	187.40*	76.532*
Denmark	1	0	-2.120	-5.487*	84.411*	51.350*
Finland	1	0	-2.956	-3.768**	740.63*	125.85*
France	2	1	-3.052	-1.815***	870.29*	111.81*
Germany	8	7	-1.218	-2.301**	487.31*	124.77*
Ireland	3	1	-2.094	-3.470**	139.21*	67.189*
Italy	4	3	0.298	-2.153**	790.46*	125.99*
Netherland	3	2	-1.870	-1.750***	107.35*	58.871*
Spain	2	1	-2.843	-2.633*	115.84*	126.62*
Sweden	1	0	-1.457	-4.936*	297.98*	122.80*
Switzerland	2	1	-1.092	-3.943**	108.51*	126.53*
the UK	1	0	-2.095	-4.229**	632.83*	106.74*

Belgium	0	1	-0.190	-6.520*	274.16*	122.37*
Denmark	1	0	-3.928	-7.018*	159.91*	71.590*
Finland	3	0	-2.794	-7.890*	80.606*	49.938*
France	1	0	-2.979	-7.988*	153.06*	70.503*
Germany	1	0	-1.752	-7.673*	69.883*	45.665*
Ireland	3	1	-2.310	-6.983*	419.34*	98.426*
Italy	1	0	-1.919	-36.151*	57.651*	40.181*
Netherland	1	0	-1939	-8.130*	521.39*	103.73*
Spain	1	0	-2.764	-8.538*	106.94*	58.970*
Sweden	1	0	-1.886	-7.862*	67.858*	44.923*
Switzerland	1	0	-1.998	-8.335*	352.82*	94.856*
the UK	1	0	-2.498	-8.779	8.955**	8.497**

Note: Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherland, Spain, Sweden, Switzerland, and the UK represent natural logarithm of real estate and stock price indices. Optimum lag is selected according to the AIC.
* ,** and *** denote rejection of null hypothesis at 1, 5 and 10%, respectively.

Methodology

Multivariate GARCH (MGARCH) models have been found more effective in analyzing the volatility spillover effects in the markets compared to univariate models. In the univariate models, the time series may be studied independently and each of them is categorized by its own mean and autocovariance function, thereby implying a failure to consider possible cross-market dependence among the time-series.

Engle and Kroner (1995) developed many various MGARCH models (diagonal, BEKK, constant conditional correlation and dynamic conditional correlation) with differences in the conditional variance-covariance matrix of equations. For the purpose of the current analysis, the BEKK (Baba, Engle, Kraft and Kroner) model is employed to investigate the spillover effects between housing and stock market, because it has enough generality to allow the conditional variances and covariances of the markets to influence each other. Moreover, it does not require a large number of parameters to be estimated (Karolyi, 1995).

Firstly, the following VAR-MGARCH model is written to estimate the conditional mean equation:

$$R_t = \mu + \delta R_{t-1} + \varepsilon_t \quad (1)$$

$$\varepsilon_t | I_{t-1} \sim N(0, H_t) \quad (2)$$

where R_t is $nx1$ vector of daily returns at time t for each market, μ, the $nx1$ vector represents constant term, ε_t is $nx1$ vector of random errors, which presents the innovation for each markets at time t with its corresponding nxn conditional variance-covariance matrix, H_t. I_{t-1} is the market information available at time t - 1. The diagonal and off-diagonal elements of the matrix δ measure the own market mean spillovers and cross-market spillovers. Specifically, the estimate of the element δ_{ij} of the matrix A explore the interdependence between two markets in terms of returns, meaning that current period returns in market i are influenced by last period returns in market j, whereas δ_{ji} measures the effect in opposite direction.

Following the multivariate BEKK-GARCH (1,1) model, the conditional variance-covariance matrix is formulated as follows:

$$H_t = C^{'}C + A^{'}\varepsilon_{t-1}\varepsilon_{t-1}^{'}A + B^{'}H_{t-1}B \quad (3)$$

where H_t is defined as (2x2) conditional variance-covariance matrix of the residuals; C is a (2x2) upper triangular matrix of constants for the pair of markets; A is a (2x2) matrix of ARCH coefficients, which capture the effects of own shocks and cross-market shock interactions; and B is a (2x2) matrix of GARCH coefficients, which capture the own market volatility persistence and the volatility transmissions between the markets. The second moment can be expressed by:

$$H_t = \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}^{'} \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^{'} \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}^{'} H_{t-1} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \quad (4)$$

Eq. (4) can take the following form:

$$h_{11,t} = c_{11}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + b_{11}^2h_{11,t-1} + 2b_{11}b_{21}h_{12,t-1} + b_{21}^2h_{22,t-1} \quad (5)$$

$$h_{12,t} = c_{11}c_{21} + a_{11}a_{12}\varepsilon_{1,t-1}^2 + (a_{21}a_{12} + a_{11}a_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}a_{22}\varepsilon_{2,t-1}^2 + b_{11}b_{12}h_{11,t-1} + (b_{21}b_{12} + b_{11}b_{22}) + h_{12,t-1} + b_{11}b_{22}h_{22,t-1} \quad (6)$$

$$h_{22,t} = c_{21}^2 + c_{22}^2 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + b_{12}^2h_{11,t-1} + 2b_{12}b_{22}h_{12,t-1} + b_{22}^2h_{22,t-1} \quad (7)$$

Conditional variances of the two variables, e.g. real estate and stock markets, are represented by Eq. (5) and Eq. (7), whereas Eq. (6) expresses the conditional covariance $h_{12,t}$ which captures the relationship between the real estate and stock market returns. ARCH effect, the effect of a previous shock on the volatility of the same variable, is shown by the parameters (a_{11}, a_{22}) and the degree of volatility persistence is represented by the GARCH parameters, (b_{11}, b_{22}).

The off-diagonal parameters of A and B matrices, a_{12} *and* b_{12} measure the cross-market effects of shocks and volatility transmission from real estate market returns to stock market returns, whereas a_{21} and b_{21} measure the effects in the opposite direction.

The parameters of BEKK-MGARCH model is estimated through the use of maximum likelihood method. The conditional log likelihood function *L(ϑ)* are represented as follows:

$$L(\theta) = \sum_{t=1}^{T} L_t(\theta), \tag{8}$$

$$L_{t=} - ln2\pi - \frac{1}{2} ln|H_t(\theta)| - \frac{1}{2}\varepsilon'(\theta)H_t^{-1}(\theta)\varepsilon_t(\theta)$$

Where T is the number of observations, ϑ denotes the parameter vector to be estimated. The parameters are estimated using a combination of the standard gradient-search algorithm Broyden-Fletcher-Goldfarb-Shanno (BFGS), and simplex algorithm.

Empirical Results

The estimates of the VAR-BEKK-GARCH model for real estate and stock markets across twelve European countries are reported in Table 3. The findings are partitioned into two panels: the former panel, Panel A, presents the results of the conditional mean equation, while the latter, Panel B, depicts the results of conditional variance equation. Turning first to Panel A, both current real estate and stock markets returns are influenced by their own past returns for all the sample countries, with the exception of Belgium and Spain, respectively, shown as the statistically significant diagonal elements of δ matrix, δ_{11} and δ_{22}. Regarding these findings, lagged values of returns can be used to estimate the current values of returns for both markets. The mean spillovers between the real estate and stock markets are represented by the significance of estimated coefficients, δ_{12} and δ_{21}. This influence suggests that lagged returns in one market can be used to forecast the current returns in another, indicating short-term predictability in real estate and stock price changes. As noted in Table 3, there exists uni-directional, bi-directional and no mean spillovers between real estate and stock markets in all selected European countries. Belgium, Denmark, Netherland and Sweden experience uni-directional spillover in mean from real estate to stock markets, implying that the lagged values of returns on real estate market significantly affect stock market returns, which mean spillover from the stock to real estate markets is only observed for Switzerland. Interestingly, among all sample countries a bi-directional mean spillover effect is evident only for Italy.

The volatility spillover effects, which are captured in the variance equation of the estimated VAR-BEKK-GARCH model, are presented in Panel B of Table 3. Statistically significance was found for all diagonal elements of matrix *A*, a_{11} and a_{22} , which measure the past shock effects of each market on the current volatility, and also for all the diagonal parameters of matrix *B*, b_{11} and b_{22}, which measure past volatility effects on the current conditional volatility. These findings reveal the evidence of ARCH and GARCH effects in all countries. Focusing on the off-diagonal parameters, a_{12} and b_{12}, the past shocks and historical conditional volatility in real estate markets influence the conditional variance of the stock markets in Denmark, Finland, Ireland and Spain. However, only the existence of shock transmission from the previous shocks in real estate markets affects the conditional variance for the stock markets of Spain, Sweden, Switzerland and the UK. Thus, it is particularly interesting to observe the extent of shock and volatility transmission from stock to real estate markets. Concerning the estimates of the parameter, a_{21}, the past stock market shocks play a crucial role in explaining the time-dynamics of conditional volatility of real estate markets in the case of seven countries - Finland, Germany, Italy, Spain, Sweden, Switzerland and the UK. On the other hand, the past volatility of the stock markets in Ireland, Spain, Sweden, Italy and Netherland, represented by b_{21} has statistically significant effects on the real estate return volatility.

Table 3. *Estimated results of volatility spillover between real estate market and stock markets returns based on the full VAR-BEKK-GARCH model*

	Belgium	*Denmark*	*Finland*	*France*	*Germany*	*Ireland*	*Italy*	*Netherland*	*Spain*	*Sweden*	*Switzerland*	*the UK*
Panel A: Conditional Mean Equation												
$\delta(1)_{11}$	0.035	0.593	0.748	0.958	0.224	0.546	0.801	0.656	0.759	0.630	0.515	0.824
	[0.723]	[0.000]*	[0.000]*	[0.000]*	[0.026]**	[0.000]*	[0.000]*	[0.000]*	[0.000]*	[0.000]*	[0.000]*	[0.000]*
$\delta(1)_{12}$	0.025	0.025	0.0003	0.0002	-0.012	0.022	-0.006	0.026	0.002	0.028	-0.006	0.004
	[0.032]**	[0.079]***	[0.974]	[0.953]	[0.164]	[0.156]	[0.016]**	[0.001]*	[0.887]	[0.010]**	[0.594]	[0.794]
μ_1	0.007	0.003	0.001	-0.0006	0.0003	0.005	0.001	0.002	0.002	0.005	0.0009	0.002
	[0.000]*	[0.005]*	[0.317]	[0.146]	[0.683]	[0.001]*	[0.000]*	[0.006]*	[0.141]	[0.000]*	[0.373]	[0.025]**
$\delta(1)_{21}$	0.018	0.228	0.546	0.051	0.342	0.279	0.953	0.553	0.085	-0.290	-1.225	-0.041
	[0.970]	[0.445]	[0.140]	[0.926]	[0.656]	[0.296]	[0.039]**	[0.139]	[0.770]	[0.462]	[0.000]*	[0.874]
$\delta(1)_{22}$	0.280	0.339	0.337	0.347	0.353	0.389	-0.087	0.234	0.258	0.415	0.377	0.209
	[0.003]*	[0.000]*	[0.000]*	[0.000]	[0.000]*	[0.000]*	[0.000]*	[0.007]*	[0.000]	[0.000]*	[0.000]*	[0.013]**
μ_2	0.010	0.015	0.019	0.010	0.008	0.015	0.042	0.008	0.011	0.018	0.010	0.012
	[0.178]	[0.025]**	[0.064]***	[0.179]	[0.232]	[0.036]**	[0.000]*	[0.176]	[0.113]	[0.013]**	[0.046]**	[0.017]*
Panel A: Conditional Variance Equation												
c_{11}	0.005	0.003	0.002	0.002	0.0004	0.010	0.0003	0.006	-0.006	0.002	0.0007	0.002
	[0.390]	[0.226]	[0.020]**	[0.000]*	[0.746]	[0.058]***	[0.788]	[0.000]*	[0.021]**	[0.012]**	[0.469]	[0.272]
c_{21}	0.030	0.010	0.032	0.030	-0.025	0.032	0.057	0.041	0.045	0.027	-0.010	-0.032
	[0.641]	[0.676]	[0.035]**	[0.546]	[0.024]**	[0.176]	[0.092]***	[0.000]*	[0.000]*	[0.004]*	[0.188]	[0.016]**
c_{22}	-0.032	0.039	-0.000	0.044	-0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000
	[0.655]	[0.000]*	[0.999]	[0.337]	[0.999]	[0.999]	[0.999]	[0.999]	[0.999]	[0.999]	[0.999]	[0.999]
α_{11}	0.207	0.416	0.399	0.696	0.344	0.340	0.862	0.831	0.493	0.371	0.177	0.607
	[0.182]	[0.003]*	[0.000]*	[0.000]*	[0.000]*	[0.007]*	[0.000]*	[0.000]*	[0.000]*	[0.000]*	[0.004]*	[0.000]*
α_{12}	1.136	2.239	1.229	-1.373	-0.725	1.260	0.786	-0.212	-1.358	3.046	-1.672	0.888
	[0.184]	[0.003]*	[0.058]***	[0.179]	[0.342]	[0.000]*	[0.332]	[0.630]	[0.046]**	[0.000]*	[0.000]*	[0.067]***
α_{21}	-0.007	-0.009	0.024	0.004	0.020	0.031	0.029	0.024	0.075	0.036	0.021	-0.052
	[0.672]	[0.702]	[0.024]**	[0.472]	[0.000]*	[0.309]	[0.000]*	[0.127]	[0.003]*	[0.025]**	[0.077]***	[0.018]**
α_{22}	0.431	0.247	0.386	0.151	0.146	0.392	-0.255	0.591	0.271	-0.277	0.327	0.302
	[0.000]*	[0.014]**	[0.001]*	[0.280]	[0.146]	[0.000]*	[0.123]	[0.000]*	[0.016]**	[0.019]**	[0.000]*	[0.050]**
B_{11}	0.874	0.840	0.876	0.736	0.894	0.404	0.667	0.289	0.016	0.872	0.961	0.799
	[0.000]	[0.000]*	[0.000]*	[0.000]*	[0.000]*	[0.031]**	[0.000]*	[0.206]	[0.920]	[0.000]*	[0.000]*	[0.000]*
B_{12}	-1.958	-0.790	-0.819	0.849	2.609	2.069	-0.255	0.608	2.830	-0.095	-0.100	0.383
	[0.479]	[0.010]**	[0.046]**	[0.314]	[0.177]	[0.005]*	[0.625]	[0.246]	[0.000]*	[0.800]	[0.389]	[0.382]
B_{21}	0.014	0.038	-0.009	-0.009	0.022	-0.186	0.010	-0.064	-0.153	-0.016	0.009	-0.015
	[0.509]	[0.341]	[0.106]	[0.659]	[0.399]	[0.000]*	[0.098]***	[0.000]*	[0.000]*	[0.012]**	[0.109]	[0.618]
B_{22}	0.570	0.582	0.870	0.722	-0.899	0.488	0.746	0.677	-0.539	0.835	0.894	0.750
	[0.015]	[0.000]*	[0.000]*	[0.004]*	[0.000]*	[0.000]*	[0.025]**	[0.000]*	[0.001]*	[0.000]*	[0.000]*	[0.000]*

Notes: μ_1 and μ_2 are constant term of the mean equations. 2. $\delta(1)_{11}$ and $\delta(1)_{22}$ capture variables' own lagged effects in mean, i.e. the dependence of the daily returns in the market on its lagged value, which variable 1 denotes the
real estate market and variable *2* denotes the stock market. 3. $\delta(1)_{12}$ stands for lagged spillover effects in mean from real estate to stock market and $\delta(1)_{21}$ indicates the same effect in the opposite direction. 4. c_{11}, c_{21} and c_{22} are
constant terms of the variance equations. 5. α_{11} and α_{22} represent the ARCH effect in two variables, respectively. 6. α_{12} measures the spillover effect of a previous shock in commodity market on the current volatility of stock market
and α_{21} measures the spillover effect in the opposite direction. 7. B_{11} and B_{22} indicate the GARCH terms, which measure volatility persistence of each series. 8. B_{12} measures the spillover effect of the last period's variance of real estate
market on the current variance of stock market. 9. B_{21} measures the spillover effect in the opposite direction. 10. Numbers in square brackets correspond to t-statistics.
* , ** and *** indicate statistical significance at the 1%, 5% and 10% level respectively.

Regarding the cross-market spillover effects, there exist bidirectional shock transmission in Finland, Spain, Sweden, Switzerland and the UK, while bidirectional volatility transmission is found only in Ireland and Spain. A notable finding is that a bidirectional volatility spillover is observed for Spain only. These bidirectional volatility spillover effects between the two markets indicate that the fluctuations in one market impact the other, and therefore, both markets contain information that can affect the other.

More interestingly, only for Belgium and France, for which none of the off-diagonal parameters are statistically significant, is there no lead-lag relationship between real estate and stock markets. It should be noted that this absence of volatility interaction may be due to masking by the extreme volatility phase of the financial markets experienced during the 2007 Great Financial Crises.

Conclusion

This study explores time-varying volatility spillover to gain further insight into the degree of interdependence among twelve European real estate and stock markets (Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherland, Spain, Sweden, Switzerland, and the UK), by investigating the nature of mean and volatility spillovers in these markets.

The main findings can be summarized as follows. In terms of mean spillover effects, Belgium, Denmark, Netherland and Sweden experience uni-directional spillover in mean from real estate to stock markets, whereas the mean spillover in the reverse direction is only observed in Switzerland. There exists bi-directional spillover effect only in the case of Italy. These results confirm the existence of lead-lag relationship in mean between real estate and stock markets in some European countries. Turning to the volatility spillover results, among all the European countries, only Belgium and France experienced no shock and volatility spillover effects between these two markets. Other European countries show more or less uni-directional and/or bi-directional spillovers. In sum, these findings reveal that either market can be used to forecast the volatility of the other in these European countries. Understanding information transmission between real estate and stock markets is critical for risk management and economic policy. The time-varying spillover effects have implications both for investors and portfolio managers, who can use such information to rebalance their portfolios and asset allocation across different markets to achieve efficient portfolio diversification and maximize investment returns. Moreover, hedging an investment vehicle is currently almost as important as asset allocation. Since volatilities indicate risks, volatility transmissions open up a new area for tailor-made financial products that allow investors to benefit from sudden changes in market volatility. Therefore, the results of this study can help gauge which European countries are more sensitive to the real estate and stock market volatility, and how this sensitivity can be translated into increased hedging performance. Particularly, the findings provide investors with important information concerning the substitutability of these two assets. Also it provides policy makers with information about the mechanisms by which these two markets may interact, and their relationship with the macroeconomic characteristics of the economy, because their close interrelation means that both may be exposed to same type of macroeconomic and financial shocks. In sum, the stock and real estate markets may show various interrelationships under different economic and political policy environments as evidence by the empirical results from these twelve developed countries.

Our findings indicate possible research avenues leading to a clearer understanding of the information transmission between real estate and stock markets and their role in explaining portfolio diversification benefits. Such an avenue would explore not only the real estate and stock markets, but also the various institutional characteristics and market structures that exist in different countries. Further research in this field could be conducted with a wide range of alternative volatility measures, and also with the inclusion of characteristics of recent financial crises into the investigated analysis to understand their effects.

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