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An International Perspective of Volatility Spillover Effect: The Case of REITs

Ehsan Nikbakht[a], Manuchehr Shahrokhi[b], Andrew C. Spieler[c]
[a] *Professor of Finance, Zarb School of Business*
Hofstra University, Hempstead, NY
finezn@hofstra.edu
[b] *Professor of Finance, California State University, Fresno*
mshahrok@csufresno.edu
[c] *Professor of Finance, Zarb School of Business*
Hofstra University, Hempstead, NY
Andrew.C.Spieler@hofstra.edu

ABSTRACT

We study the 1999-2011 period for volatility spillover between US and European real estate markets. The sample period is divided into pre-crisis (1999-2007) and post-crisis (2007-2011) periods. Real estate investment is proxied by the performance of equity REITs, private real estate indices and real estate firms. We document an asymmetric volatility spillover effect from U.S. markets to European markets. The primary result is the finding of volatility transmission from U.S. real estate markets to European real estate markets emanating from public U.S. real estate investment (S&P REIT index). However, there is no strong evidence that European markets spill over to U.S. real estate markets for either public or private real estate.

JEL Classifications: *C30; G10; R30*

Keywords: *volatility spillover; GARCH; REITs*

I. INTRODUCTION

In managing a global portfolio where the risk-adjusted return, such as the Sharpe ratio, is a primary focus, the size of correlation and the change in correlation over time are critical factors. Global diversification is beneficial to the extent that managers are successful in risk reduction, i.e. allocating capital to low correlation markets. Risk reduction is not easily attainable once co-movements between the securities or between the markets increase significantly usually due to systematic events like the Asian Financial Crisis in 1997 and real estate meltdown in 2007. In particular, investors add real estate to an existing portfolio to increase yield, hedge against inflation, and reduce the overall risk of the portfolio. Investing in international real estate properties and real estate investment trusts (REITs) became increasingly popular after the collapse of technology firms and the rise in bankruptcies in the early 2000s in the United States and other countries. The purpose of this paper is to examine the volatility transmission effect from the U.S. real estate (public and private) to the real estate markets of Europe and vice versa. Returns, volatility, and the risk/return ratios of the indexes are also examined.

We study the 1999-2011 period for volatility spillover between the U.S. and European real estate markets. The sample period is divided into two mutually exclusive sub periods: pre-crisis (1999-2007) and post-crisis (2007-2011). Note the rumors about Lehman Brothers were spreading in late 2007, and the actual bankruptcy occurred in 2008 followed by other crisis events. Therefore, splitting the period around the year 2007 is warranted in terms of the timing of the crisis. Real estate investment performance is proxied by several measures for robustness: equity REITs, private real estate indices and real estate firms. The primary result is the finding of volatility transmission from public U.S. real estate markets to public European real estate markets. However, there is no strong evidence that European markets spillover to U.S. real estate markets for either the public or private real estate.

There is a sizeable volume of research in the area of intermarket volatility effect. The authors believe this research is relatively unique not only in terms of focusing on REITS and the periods before and after crisis, it also examines the volatility effect in four directions: the US (private) to Europe, Europe to the U.S. (private), the U.S. (public) to Europe, and Europe to the U.S. (public).

We organize this paper into six sections. In Section II, we offer a selected review of the literature on volatility transmission effect. Sections III and IV describe the methodology and the data used in this study, respectively. The empirical results are provided in Section V followed by a summary conclusion in Section VI.

II. LITERATURE REVIEW

A number of studies focused on inter-market volatility transmission effect after the financial crisis of the 1990s and the early 2000s during which corporate bankruptcies increased and many technology firms failed. Research on correlation breakdown and volatility spillover within and between domestic and global markets received more attention after the real estate and financial crisis, which began around 1996. Koutmos and Booth (1995) empirically documented how the announcement of bad news that affects one region easily spreads to several other regions. Specifically, they described the case of inter-market spillover effects among the markets in Japan, the United States and United Kingdom. Using autoregressive models, Reyes (2001) focused on market value indexes and showed that not only does the inter-market spillover exist, but it is also influenced by firm size (market capitalization). In a similar study of the U.S. and U.K. markets, Michayluk, Wilson and Zurbruegg (2006) applied an asymmetric dynamic covariance model in which they identified a directional spillover effect between markets in the US and Europe. Guirguis, Giannikos and Garcia (2007) conduct an empirical inquiry into the price transmission mechanism in the housing markets between the cities with different populations in Spain. Through a bivariate GARCH model, they demonstrated that there is a "unidirectional" spillover price effect from the larger cities to the smaller cities. The spillover effect consistency for different REIT types is well documented in Lee and Stevenson (2005). Their findings are supportive of the spillover effect reported in a prior study by Stevenson (2002).

Cauchie and Hoesli (2006) find that there is a spillover effect and integration between different assets classes; specifically, the equity and real estate interaction is most affected. The authors use Swiss data in a global framework including stocks, bonds, and real estate mutual funds on a quarterly basis. They reject the notion of a direct connection between fixed income and real estate and support "effective segmentation" between the markets. Kleiman, Payne and Sahu (2002) conducted tests for co-integration of equity markets and real estate for Europe, Asia and North America. Using monthly data from 1983 to 1997, the researchers report that these global markets were not co-integrated during the fifteen year period. Tests for random walk and co-integration were conducted using monthly returns from December 1983 through December 1997. Their results support the random walk hypothesis for the REIT and equity markets.

Tsai and Lee (2012) examined the linkage between REITs in the Asia-Pacific region. In particular, they compared the data for a small group of Asian countries with those of the Japanese and the U.S. markets. The results indicate that the markets in Korea and Japan were integrated, whereas there was no integration between other Asian countries and Japan. At the same time, they showed integration of Korea, Taiwan, Hong Kong and Singapore vis-à-vis the U.S. market. Overall, they conclude that there is a significant integration between the U.S. and Asian REITs. Further, their results indicate that the inter-market linkage becomes weaker following the global financial crisis. It is possible that the linkage was more of a "contagion effect" rather than a systemic integration, as the authors explain.

Chen and Liow (2006) study volatility transmission effect among both the equity and real estate markets for Australia, Hong Kong, Japan, Singapore, the U.K. and U.S. They use a vector autoregressive model to trace and measure the size of the spillover effect. They report a significant "multidirectional" effect over a period of sixteen years from 1990 to 2005. In addition, the results indicate a more pronounced transmission effect among the Asian markets. Li, Lin and Jin (2012) investigate whether REIT return volatility has a spillover effect among a group of countries from different continents. They check for geographic risk (transfer risk hypothesis) under the assumption of international market integration as well as country specific risk (non-transportable risk hypothesis). In the latter case, the argument is that risk factors are often country or regionally contained. Using both GARCH and EGARCH models, they report a spillover effect among three countries, i.e., Japan, the U.K. and the U.S. Hoseli and

Reka (2011) analyzed twenty years of data to examine the interaction between global real estate markets and between real estate markets and equity markets. They primarily use several forms of asymmetric correlation analyses including the BEKK (Baba, Engle, Kraft and Kroner) model and report the existence of spillover effects within the U.S. markets and in interaction with other markets including Australia in that period.

Chang, Chen, and Leung (2012) extend a similar work for the U.S. and Hong Kong markets. They examine if volatility in both financial and housing markets in the U.S. has affected the asset returns and the GDP growth rate of Hong Kong. They conclude, despite reports of no linkage in previous studies, the asset returns and the GDP growth in Hong Kong were significantly affected following the U.S. stock turmoil, widening of the TED spread (Treasury-Eurodollar spread) and other market and credit spreads.

Research on volatility spillover effect has not been limited to a particular industry, sector, or region. Commodities, private equity funds, and foreign exchanges in the global market are all candidates for the study of possible inter-market volatility effects. For example, Baele (2005) investigated the issue in a global setting including Europe and reported significant spillover effects across different regions and local markets. Yet, in most studies, the spillover effect among various markets, especially in the case of real estate, was analyzed generally using combined time series, which did not separate the data before and after the financial and real estate crisis of 2006-2007. One contribution of this paper is to examine whether there has been a volatility transmission (spillover) effect between the U.S. real estate markets (private real estate investments and REITs) to those of selected public European real estate markets in three time periods: 1999 to 2007 (before the crisis), 2007 to 2011 (after the crisis) and the full period of 1999 to 2011.

III. METHODOLOGY

We use a modified version of GARCH to incorporate the spillover effect as explained below.

Engle (1982) derives his classic equation to measure the changing volatility over time. In simple terms, the conditional variance is a linear function of squared error terms plus an additional factor X. Returns and volatility are presented in the form of a basic ARCH model:

$$R_t = \alpha + \in_t \tag{1}$$

$$h_t = a + c \in_{t-1}^2 + fX_t \tag{2}$$

where the value of a is positive and the value of c and f are ≥ 0.

In this model, h_t (the conditional variance at time t) is a function of the squared error term and factor X could be a possible autonomous variable. The model is flexible enough to incorporate additional squared error terms from previous periods. Later, Bollerslev (1986) extended the conditional variance h to be a function of both its previous period's error squared as well as its conditional variance. The result became the generalized GARCH (1, 1) model, which defines the conditional variance h as follows:

$$h_t = a + bh_{t-1} + c \in_{t-1}^2 + fX_t \tag{3}$$

It is important to note that the conditional mean in Engle, Lilien and Robins (1987) is a function of the conditional variance at the time t. This GARCH (1, 1) mean model can be expressed as $R_t = \alpha + bh_t + \in_t$, where the conditional variance is the same as defined in GARCH (1, 1) (Enders 2012).

Building upon the above model, we applied the modified GARCH version of Hamao, Masulis and Ng (1990) using the univariate GARCH methodology to investigate relations between the markets and for the period under study. We use GARCH (1, 1) to measure the magnitude of the volatility. A number of studies have demonstrated that the simple version of GARCH, i.e., GARCH (1, 1), is more effective than higher order GARCH models. In general, GARCH (1, 1) is a parsimonious model that helps avoid over-fitting and does not violate the positive-value-constraint assumption (Enders 2012).

In our approach, we estimated GARCH (1, 1) models for each one of the markets individually. Then, the squared residuals of the previous estimated models were used as a "regressor" in the variance equation of the other markets. This intuitive model, as applied in a number of studies starting with Hamao et al. (1990), can measure the volatility of each market and relative volatility to other markets through paired regressions.

We regress the unexpected change (surprise), measured by squared residuals, in one market against the conditional variance of the other as estimated through GARCH. We run this test in both directions. One hypothesis is the spillover effect was transmitted from the U.S. to Europe; the other is from Europe to the U.S. Formally, the hypotheses are summarized below.

Hypothesis 1: Spillover effect is transmitted from private U.S. real estate markets to European real estate markets

Hypothesis 2: Spillover effect is transmitted from European real estate markets to private U.S. real estate markets

Hypothesis 3: Spillover effect is transmitted from public U.S. real estate markets to European real estate markets

Hypothesis 4: Spillover effect is transmitted from European real estate markets to public U.S. real estate markets

The following table summarizes all hypotheses for the U.S. markets (public and private) and European markets. Since most private European indices were formed more recently (compared to the private U.S. indices that existed for longer periods), we did not specifically and separately address the private Europe indices in this study.

Table 1
Hypotheses for the U.S. markets (public and private) and European markets

Hypothesis	From	To	Table
1	U.S. (private)	Europe	5, 5A, 5B
2	Europe	U.S. (private)	6, 6A, 6B
3	U.S. (public)	Europe	7, 7A, 7B
4	Europe	U.S. (public)	8, 8A, 8B

IV. DATA

The data used for this research consist of both the U.S. and European equity and real estate firms and indexes. Below is a brief introduction of the selected investments with their trading symbols as compiled from Bloomberg LP.

The S5REITS variable is the S&P U.S. REITs and is representative of the U.S. REIT market. F3REAL denotes the FTSE 350 Real Estate Index which is designed to measure the performance of real estate investments in the U.K., and is currently trading under the ticker F3REASE. The BEREALE is the BE500 Real Estate Index that was created by Bloomberg to track all companies involved in the real estate sector of the Bloomberg Europe 500 Index. It is representative of European real estate in general. Ticker DLN is the Derwent London PLC, which is a diversified REIT that focuses on central London. GFC (Gecina SA) is a large real estate company that invests in France and specializes in the rental of commercial and residential properties. HMSO (Hammerson PLC) is a diversified real estate investment company that operates throughout the U.K., France and Germany. The reason some of these large firms are included in the sample, instead of private European indexes, is the fact that some European private indices, like Moody's/RCA, were created only around 2007 and there is no data available for them before the crisis. Therefore, the inclusion of large firms from England and Europe, instead of new private indexes, in the judgment of the authors, may reveal the effect of volatility effect for both before and after the crisis in this research.

For the U.S. private real estate benchmark, the NPI (NCREIF Property Index) is selected. It is a popular index available and used in numerous academic and industry studies in real estate research. The market value of the properties included in the NPI index is approximately $325 billion (as of November 2011). Thirteen years of data observations for each index were collected for this study. All data were extracted from Bloomberg LP.

First, a correlation coefficient matrix was developed for the data to investigate possible high pair-wise correlations, among the U.S. and European indexes. A one-period lead/lag was applied within each pair. After using the correlation coefficient matrix as the initial screening process, the GARCH (1, 1) model was employed to measure the magnitude and direction of the transmission volatility effect between the two markets as explained in the methodology section.

V. ANALYSIS OF RESULTS

A. Descriptive Data

Tables 2, 3 and 4 display the return, risk and the risk/return ratios of the U.S. and European indexes in three periods: 1999-2006, 2007-2011 and the entire period of 1999-2011. In the first period, the S&P REITs outperformed both the NPI index and the European REITs average index. Over the same period, the European REITs average index (22% annual return) outperformed the U.S. Real Estate Private Investment Index. Adjusted for volatility, using the coefficient of variation (ratio of volatility to return for the same period), the U.S. NPI Index and the S&P REITs maintained the lowest (most favorable) ratios of 7.76 and 11.69, respectively. The corresponding risk/return ratio for

Table 2
Annual returns of US Real Estate Index (NPI), S&P REIT, and S&P Equity Index (2000-2011)

Year	Real Estate Private Investment NPI (%)	S&P REIT (%)	S&P 500 Equity (%)
1999	12.89	25.03	19.53
2000	13.29	27.97	-10.14
2001	1.57	13.82	-13.04
2002	6.07	4.12	-23.37
2003	11.88	34.77	26.38
2004	21.21	30.98	8.99
2005	26.20	11.18	3.00
2006	13.14	35.03	13.62
2007	15.05	-16.21	3.53
2008	-16.10	-37.95	-38.49
2009	-7.33	26.70	23.45
2010	-2.03	23.93	12.78
2011	1.88	3.70	0.0000

Source: Bloomberg LP, 2012; Morningstar Inc., 2013; S&P Dow Jones Indices McGraw-Hill Financial LLC, 2013

Table 3
Annual returns of selected European real estate indices

Year	F3REAL[a]	BEREALE[b]	DLN[c]	GFC[d]	HMSO[e]
1999	0.190330	-0.021400	0.397010	-	-
2000	0.212588	-0.023300	0.427184	-	0.247978
2001	-0.109200	-0.149640	-0.106120	-	-0.042120
2002	-0.151700	-0.169260	-0.170470	-	0.066516
2003	0.417613	0.288513	0.366972	0.124031	0.368922
2004	0.286566	0.189362	0.510067	1.513793	0.341313
2005	0.247605	0.199125	0.280889	0.330590	0.176742
2006	0.251340	0.348097	0.455239	0.494845	0.543053
2007	-0.357520	-0.353320	-0.325700	-0.259860	-0.350030
2008	-0.472410	-0.731590	-0.487270	-0.537460	-0.478050
2009	-0.457090	-0.855131	-0.820690	-0.533840	-0.207480
2010	-0.390080	-0.789900	-0.789300	-0.465320	-0.186500
2011	-0.340300	-0.548530	-0.654320	-0.378210	-0.165980

Source: Bloomberg LP, 2010

[a] F3REAL is the FTSE 350 Real Estate Index which is designed to measure the performance of real estate investments in the U.K., and it is currently trading under the ticker F3REASE.

[b] BEREALE is the BE500 Real Estate Index that was created by Bloomberg in order to track all companies involved in the real estate sector of the Bloomberg Europe 500 Index, and is representative of European real estate as a whole.

[c] DLN is the Derwent London PLC which is a diversified REIT that focuses on central London.

[d] GFC is Gecina SA, which is a real estate company that invests in France and specializes in the rental of commercial and residential properties.

[e] HMSO is Hammerson PLC, which is a diversified real estate investment company that operates throughout the U.K., France and Germany.

Source: Bloomberg LP, 2011

Table 4
Risk/return profile of U.S. and European REITs

Time Period		U.S. Real Estate Private Investment NPI (%)	U.S. S&P REITs (%)	European REITs Average Index (%)
Pre-2006	Return Before 2006 Crisis	13.28	22.86	21.80
Pre-2006	Volatility Before 2006 Crisis	7.76	11.69	10.16
Pre-2006	Risk/Return Before 2006 Crisis	0.58	0.51	0.47
Post-2006	Return After 2006 Crisis	-1.71	0.03	-0.48
Post-2006	Volatility After 2006 crisis	11.54	27.40	23.33
Post-2006	Risk/Return Ratio After Crisis	-6.76	805.77	-48.60
Full sample	Overall Return	7.52	14.08	-0.05
Full sample	Overall Risk	9.71	21.53	15.90
Full sample	Overall Risk/Return Ratio	1.30	1.53	-318

the European REITs was higher at 13.16. After 2006, Table 4 indicates that the volatility of both the U.S. and European indexes increased. The S&P REITs volatility jumped from 11.69% to 27.40%. It is observed that as volatility increased, the corresponding returns deteriorated as well. The volatility for the European REITs increased from 13.16% to 23.33% and return decreased from 21.80% (pre-2006) to -0.48% (post-2006). It is interesting to observe that the risk/return ratios of both the European and US indexes worsened, i.e. increased or became negative, because of their negative returns. Among the selected European indexes, the BEREALE (Bloomberg European Real Estate Index) had the worst performance of -73% in the year 2008. Among the five European indexes studied in this research, DLN (Derwent London PLC) suffered the smallest decline. Overall, both the annual returns and risk/return ratios became smaller and less favorable after the crisis of 2006.

B. Correlation and Inter-market Transmission Effect

Before investigating a possible volatility transmission effect, we checked the significance of correlation between various pairs of the U.S. and European indexes. The statistics from Table 5 show that there is a significant correlation between the following eight pairs of indexes at 5% significance level:

- The FTSE 350 Real Estate Index and the U.S. S&P REITs
- The FTSE 350 Real Estate Index and the U.S. Real Estate Private Investment NPI
- The Bloomberg European 500 Real Estate Index and the U.S. S&P REITs
- The Bloomberg European 500 Real Estate Index and the U.S. Real Estate Private Investment NPI
- The Derwent London PLC and the U.S. S&P REITs
- The Derwent London PLC and the U.S. Real Estate Private Investment NPI
- The FTSE 350 Real Estate Index and the S&P 500 Equity
- The Bloomberg European500 Real Estate Index and the S&P 500 Equity

Table 5
Correlation coefficient matrix

	Real Estate Private Investment NPI (%)	S&P REITs (%)	S&P 500 Equity (%)
F3REAL	0.63	0.37	0.54
	(3.23)**	(2.94)**	(3.94)**
BEREALE	0.82	0.92	0.34
	(3.56)**	(4.21)**	(2.99)**
DLN	0.72	0.67	-0.37
	(4.32)**	(3.94)**	(-1.56)
GFC	-0.23	-0.27	-0.17
	(-1.23)	(-1.45)	(-1.43)
HMSO	-0.32	-0.29	-0.31
	(-1.54)	(-1.63)	(-1.47)

The t-values are in parentheses. The values significant at 10% are marked with *, values significant at 5% are marked with **, and values significant at 1% are marked with ***. Values marked with # exceed the critical levels for the likelihood ratios.

The correlation between the other pairs of indexes was not significant at the 5% significance level. For example, the GFC France and the HMSO of Germany, France and U.K. did not show a significant correlation with U.S. Real Estate Private Investment NPI, U.S. S&P REITs, and S&P Equity. A plausible explanation is that the U.S. Real Estate Private Investment NPI is not a transaction-based index. In addition, the GFC France and HMSO of Germany, France and U.K. are real estate firms; they are not full-fledged real estate indexes. A real estate firm, unlike a diversified real estate portfolio index, has its own idiosyncratic volatility and may not be significantly correlated with the total market fluctuations. Therefore, excluding the European real estate firms from the sample, it is clear that there is a significant correlation between the U.S. S&P REITs and the European Real Estate Indexes.

The GARCH results to test Hypothesis 1 from the U.S. to Europe, for all three periods (before crisis, after crisis, and the full period of 1999 to 2011) are displayed in Table 6. In none of those periods do we observe any significant volatility transmission (spillover) effect from the U.S. Real Estate Investment NPI to other European indexes. The absence of transmission effect, even after the crisis, can likely be attributed to the construction methodology of this particular and popular U.S. real estate price index which is based on market appraisal which imputes a well-known smoothing effect into the data. Stated differently, the volatility transmission effect between the U.S. NPI Private Real Estate Index to all selected European real estate indices, indicates a confidence level below 90%.

Hypothesis 2 also examines the reverse direction (possibility of transmission from Europe to the U.S.) for all three periods using the same NPI index. The output is summarized in Table 7. Again, except for a few isolated statistics, we cannot support the existence of volatility transmission from public European real estate to private U.S. real estate. This may further support our plausible explanation that the NPI Index, used often in applied research, may not reveal the possibility of an underlying price transmission in either direction: from the U.S. to Europe or vice versa. In contrast to the above, the GARCH coefficients in Table 8 reveal a very different result.

Table 6
Inter-market transmission effects from U.S. Real Estate NPI Index to selected European real estate indices 1999-2011

$$R_t = \alpha + \beta h_t + \gamma \in_{t-1};\ h_t = a + bh_{t-1} + c \in_{t-1}^2$$

Panel A: Before Crisis

Coefficients of GARCH	From NPI to F3REAL	From NPI to BEREALE	From NPI to DLN
α	0.0032	0.0002	0.00019
	P= 0.113	P=0.135	P=0.184
β	0.0321	0.057	0.0372
	P= 0.186	P=0.166	P=0.174
γ	0.4685	0.4527	0.0533
	P=0.154	P=0.156	P=0.123
a	0.0051	0.0032	0.00643
	P=0.147	P=0.132	P=0.129
b	0.1566	0.1276	0.1234
	P=0.189	P=0.154	P=0.179
c	.	.	.
Kurtosis coefficient	1.39	2.62	2.12
Likelihood stat (L)	7.32	6.92	5.39
Null: All coefficients=0			

Note: None of the above coefficients are significant at either 5% or 10%.

Panel B: After Crisis

Coefficients of GARCH	From NPI to F3REAL	From NPI to BEREALE	From NPI to DLN
α	0.0022	0.0013	0.00021
	P= 0.131	P=0.156	P=0.197
β	0.0211	0.068	0.054
	P=0.197	P=0.186	P=0.165
γ	0.5799	0.4342	0.0421
	P=0.174	P=0.165	P=0.132
a	0.0041	0.0042	0.00733
	P=0.177	P=0.143	P=0.134
b	0.611	0.1342	0.1432
	P=0.231	P=0.164	P=0.189
c	.	.	.
Kurtosis coefficient	5.12	6.88	5.45
Likelihood stat (L)	6.12	8.72	5.82
Null: All coefficients=0			

Note: None of the above coefficients are significant at either 5% or 10%.

Panel C: Full Period

Coefficients of GARCH	From NPI to F3REAL	From NPI to BEREALE	From NPI to DLN
α	0.0031	0.0012	0.00017
	P= 0.118	P=0.146	P=0.199
β	0.0432	0.0 67	0.0421
	P=0.286	P=0.176	P=0.198
γ	0.5125	0.543	0.076
	P=0.164	P=0.175	P=0.153
a	0.0064	0.0042	0.00876
	P=0.150	P=0.135	P=0.120
b	0.1866	0.1345	0.1442

	P=0.289	P=0.144	P=0.177
c	.	.	.
Kurtosis coefficient	5.11	8.65	9.88
Likelihood stat (L)	5.77	4.78	3.87
Null: All coefficients=0			

Note: None of the above coefficients are significant at either 5% or 10%.

Table 7

Inter-market transmission effects from selected European real estate indices to U.S. Real Estate NPI Index, 1999-2011

$$R_t = \alpha + \beta h_t + \gamma \in_{t-1};\ h_t = a + bh_{t-1} + c \in_{t-1}^2$$

Panel A: Before Crisis

Coefficients of GARCH	From F3REAL to NPI	From BEREALE to NPI	From DLN to NPI
α	0.0029	0.0009	0.00432
	P= 0.131	P=0.142	P=0.187
β	0.0432	0.0587	0.0543
	P=0.186	P=0.176	P=0.178
γ	0.4673	0.4765	0.0755
	P=0.186	P=0.187	P=0.143
a	0.0261	0.0142	0.00768
	P=0.197	P=0.155	P=0.130
b	0.271	0.1354	0.1765
	P=0.231	P=0.234	P=0.232
c	.	.	.
Kurtosis coefficient	2.65	1.898	2.99
Likelihood stat (L)	7.99	6.04	3.44
Null: All coefficients =0			

Note: None of the above coefficients are significant at either 5% or 10%.

Panel B: After Crisis

Coefficients of GARCH	From F3REAL to NPI	From BEREALE to NPI	From DLN to NPI
α	0.0013	0.1322	0.1326
	P= 0.232	P=0.134	P= 0.333
β	0.0431	0.067	0.0796
	P=0.199	P=0.143	P=0.243
γ	0.1686	0.546	0.0877
	P=0.176	P=0.342	P=0.343
a	0.2350	0.0321	0.0166
	P=0.187	P=0.142	P=0.177
b	0.1777	0.1543	0.1765
	P=0.189	P=0.199	P=0.146
c	.	.	.
Kurtosis coefficient	12.88	18.99	14.887
Likelihood stat (L)	4.011	7.987	8.777
Null: All coefficients=0			

Note: Even after crisis of 2006, none of the coefficients are significant at either 5% or 10%. As noted, the reason could be attributed to the way the NPI index is constructed.

Panel C: Full Period

Coefficients of GARCH	From F3REAL to NPI	From BEREALE to NPI	From DLN to NPI
α	0.0054 P= 0.343	0.0013 P=0.243	0.00029 P= 0.266
β	0.0643 P=0.196	0.099 P=0.166	0.0654 P=0.174
γ	0.466 P=0.254	0.654 P=0.356	0.1534 P=0.129
a	0.0252 P=0.166	0.0043 P=0.137	0.00432 P=0.120
b	0.1877 P=0.344	0.1544 P=0.342	0.1999 P=0.345
c	.	.	.
Kurtosis coefficient	8.11	6.44	15.99
Likelihood stat (L) Null: All coefficients=0	6.998	8.934	5.564

Note: Using the entire period of 1999 to 2011, none of the coefficients are significant at either 5% or 10%. As noted, the reason could be attributed to the way the NPI index is constructed. The NPI is a price appraised index (not transactional).

Hypothesis 3, public U.S. real estate transmission to European real estate markets, is now analyzed. Table 8 uses the U.S. S&P REITs (in place of the NPI index) and maintains the same European real estate indexes (FTSE 350 Real Estate, Bloomberg European 500 Real Estate, and Derwent London PLC). In this set of iterations, where we incorporate the U.S. REIT Index, the transmission effect (from the U.S. to Europe) becomes statistically significant at the 5% and 10% levels. In a few cases, we observe a 1% level of significance as well. We also observe the high levels of kurtosis (possibility of fat tails around the crisis time), but in general the kurtosis coefficient hovers around 3 in most cases. The likelihood ratios, indicative if any the GARCH coefficients are different from zero, exceed the critical levels in Table 8. Overall, we tend to support that contention that there is a transmission effect from the U.S. real estate market (as measured by the S&P REIT Index) to the selected European real estate markets. In Table 9, we replicated the same GARCH test for the possibility of transmission effect from Europe to the U.S. (Hypothesis 4). Except for isolated cases, we do not observe a consistent significant flow of volatility in that direction.

This study also shows that results from research on volatility transmission effect between the European and the U.S. markets are index specific. For example, we could not determine any significant correlation between the two markets when private real estate investment proxied by NPI was used. This result is perhaps not surprising given that the NPI index is computed based on market appraisals, not market transactions. After excluding the NPI index, we observed that the values of the correlation coefficient matrix and the GARCH were mostly significant. This finding is consistent with abundant extant empirical evidence showing correlation in general has increased significantly between various markets over time. Boyer, Gibson and Loretan (1999) were among the first who identified this pattern in financial markets and referred to it as a rise in correlation breakdown. Our findings also support the conclusion of Michayluk et al. (2006) in which they identified a directional spillover effect from specific markets in the U.S. to the U.K.

Table 8

Inter-market Transmission Effects from U.S. S&P REITs to Selected European Real Estate Indexes, 1999-2011

$$R_t = \alpha + \beta h_t + \gamma \in_{t-1};\ h_t = a + b h_{t-1} + c \in_{t-1}^2$$

Panel A: Before Crisis

Coefficients of GARCH	From S&P REITs to F3REAL	From S&P REITs to BEREALE	From S&P REITs to DLN
α	0.0244	0.0445	0.0654
	P= 0.0650*	P=0.0450**	P= 0.0900*
β	0.0896	0.5981	0.645
	P=0.0150**	P=0.0344**	P=0.0901*
γ	0.677	0.7865	0.654
	P=0.0001***	P=0.0030***	P=0.0477**
a	0.45	0.34	0.67
	P=0.0469**	P=0.0325**	P=0.0287**
b	0.71561	0.81277	0.81235
	P=0.0186**	P=0.0154**	P=0.0179**
c	0.8666	0.785	0.9854
	P= 0.0333**	P=0.0432**	P= 0.0012***
Kurtosis coefficient	2.866	2.763	2.540
Likelihood stat (L)	20.11#	32.11#	19.88#
Null: All coefficients=0			

Note: The values significant at 10% are marked with *, values significant at 5% are marked with **, and values significant at 1% are marked with ***. Values marked with # exceed the critical levels for the likelihood ratios.

Panel B: After Crisis

Coefficients of GARCH	From S&P REITs to F3REAL	From S&P REITs to BEREALE	From S&P REITs to DLN
α	0.645	0.41345	0.5455
	P= 0.0110**	P=0.0430**	P=0.0675*
β	0.6754	0.964	0.324
	P=0.0188**	P=0.0166**	P=0.0175**
γ	0.485	0.427	0.0523
	P=0.0159**	P=0.0158**	P=0.0125**
a	0.764	0.843	0.866
	P=0.0432**	P=0.0321**	P=0.0128**
b	0.3566	0.7877	0.41231
	P=0.0184**	P=0.0155**	P=0.0178**
c	.345	.563	.745
	P=.083*	P=.0983*	.0865*
Kurtosis coefficient	3.14	2.87	3.66
Likelihood stat (L)	45.11#	54.12#	23.15#
Null: All coefficients=0			

Note: The values significant at 10% are marked with *, values significant at 5% are marked with **, and values significant at 1% are marked with ***. Values marked with # exceed the critical levels for the likelihood ratios.

Panel C: Full Period

Coefficients of GARCH	From S&P REITs to F3REAL	From S&P REITs to BEREALE	From S&P REITs to DLN
α	0.00333	0.0102	0.011
	P= 0.416	P=0.516	P=0.654
β	0.911	0.887	0.765
	P=0.0187**	P=0.0170**	P=0.0173**
γ	0.8766	0.988	0.765
	P=0.0174**	P=0.0196**	P=0.0176**
a	0.9871	0.754	0.632
	P=0.0157**	P=0.0175**	P=0.0154**
b	0.764	0.864	0.645
	P=0.00185***	P=0.00156***	P=000186***
c	.9612	.9722	.9645
	P=.0034***	P=.00154***	P=.00245***
Kurtosis coefficient	3.77	3.89	4.11
Likelihood stat (L)	28.11#	29.66#	27.642#
Null: All coefficients=0			

Note: The values significant at 10% are marked with *, values significant at 5% are marked with **, and values significant at 1% are marked with ***. Values marked with # exceed the critical levels for the likelihood ratios.

Table 9

Inter-market transmission effects from selected European real estate indices to U.S. S&P REITs, 1999-2011

$$R_t = \alpha + \beta h_t + \gamma \in_{t-1} \; ; \; h_t = a + b h_{t-1} + c \in_{t-1}^2$$

Panel A: Before Crisis

Coefficients of GARCH	From F3REAL to the S&P REITs	From BEREALE to the S&P REITs	From to DLN to the S&P REITs
α	0.143	0.2345	0.4389
	P= 0.234	P=0.123	P=0.197
β	0.054	0.089	0.098
	P=0.234	P=0.564	P=0.321
γ	0.643	0.098	0.0111
	P=0.066	P=0.134	P=0.125
a	0.234	0.054	0.00688
	P=0.143	P=0.156	P=0.341
b	0.01567	0.01274	0.012934
	P=0.177	P=0.158	P=0.176
c	0.0064	0.0087	0.0076
	P=0.143	P=0.189	P=0.342
Kurtosis coefficient	8.45	9.45	8.56
Likelihood stat (L)	6.011	7.0801	8.077
Null: All coefficients=0			

Note: None of the above coefficients are significant at either 5% or 10%.

Panel B: After Crisis

Coefficients of GARCH	From F3REAL to the S&P REITs	From BEREALE to the S&P REITs	From to DLN to the S&P REITs
α	0.0986	0.08876	0.0754
	P= 0.156	P=0.176	P= 0.142
β	0.0453	0.0832	0.0985
	P=0.0399**	P=0.345	P=0.0724*
γ	0.03456	0.0453	0.0633
	P=0.345	P=0.234	P=0.324
a	0.02345	0.0345	0.02345
	P=0.145	P=0.177	P=0.245
b	0.0457	0.01276	0.01745
	P=0.223	P=0.256	P=0.245
c	0.0834	0.1185	0.1543
	P= 0.078*	P= 0.113	P= 0.120
Kurtosis coefficient	6.901	7.085	4.987
Likelihood stat (L)	9.11	4.786	6.983
Null: All coefficients=0			

Note: Most coefficients are NOT significant at either 5% or 10%. The values significant at 10% are marked with *, values significant at 5% are marked with **, and values marked with # exceed the critical levels for the likelihood ratios.

Panel C: Full Period

Coefficients of GARCH	From F3REAL to the S&P REITs	From BEREALE to the S&P REITs	From to DLN to the S&P REITs
α	0.0765	0.0002	0.00019
	P= 0.118	P=0.134	P= 0.189
β	0.0435	0.0654	0.0657
	P=0.256	P=0.095*	P=0.199
γ	0.04683	0.0456	0.08976
	P=0.345	P=0.234	P=0.321
a	0.064	0.0784	0.085
	P=0.157	P=0.082*	P=0.136
b	0.2456	0.2367	0.0751
	P=0.234	P=0.154	P=0.190
c			
Kurtosis coefficient	4.88	5.45	3.13
Likelihood stat (L)	3.17	3.89	2.897
Null: All coefficients=0			

Note: Most coefficients are NOT significant, at either 5% or 10%, when the entire period is considered. The values significant at 10% are marked with *.

VI. CONCLUSIONS, POLICY IMPLICATIONS AND RECOMMENDATION FOR FUTURE WORK

This research extends previous work on volatility transmission to study the relationship between the U.S. and European real estate markets. The data used in this study covers 1999-2011 which includes the deep recession in the U.S. and European markets and concomitant decline in real estate prices. Accordingly, we subdivided the sample period into pre-Crisis (1999-2006), post-Crisis (2007-2011 and full-sample (1999-2011).

For each sub-period, a GARCH (1,1) model is used to test for volatility spillover. Specifically, volatility transmission is tested for the U.S. markets to European markets and European markets to U.S. markets for both public and private real estate price indices. Public real estate prices are proxied by S&P REITs (the U.S. markets) and FTSE 350 (the U.K. markets). The private U.S. real estate prices are proxied by NPI (NCREIF Index).

Following is a summary of findings, where "yes" means a significant directional transmission effect from one market to the other, and "no" otherwise.

Table 10
Summary of findings

Hypothesis	From	To	Before Crisis Pre-2007	After Crisis 2007-2011	Entire Period 1999-2011
1	U.S. (private)	Europe	No	No	No
2	Europe	U.S. (private)	No	No	No
3	U.S. (public)	Europe	Yes	Yes	Yes
4	Europe	U.S. (Public)	No	No	No

We document an asymmetric volatility spillover effect. As the above table shows, the only consistent evidence of volatility transmission is from U.S. public markets to European markets for both the entire sample period as well as the pre and post-crisis time periods. We also point out that there is no evidence of volatility transmission from U.S. private real estate markets to European markets or from European markets to U.S. markets (public or private) in any sub-period.

A possible caveat to the empirical results should be noted. The construction of the private real estate indices may contribute to the lack of statistical significance. In particular, the NCREIF index uses appraisals rather than market transactions for the data series. The results are broadly consistent with previous research documenting volatility spillover between the U.S. and U.K. property markets. The results are also specific to the index chose which appears to proxy for public/private investments.

We also note that our results have broader implications documenting the linkage between international markets even in real estate markets which are by nature illiquid and more heterogeneous than equity or fixed income markets. To the extent that investors form international portfolios, volatility spillover reduces the benefit of cross-border diversification. Interestingly, if the lack of spillover between private real estate markets can be confirmed by further research, including use of private real estate, this highlights the possibility of diversification benefits.

ENDNOTE

1. The NPI index includes major types of real estate in the US including business offices, residential apartments, business retail centers, shopping centers, warehouse and manufacturing properties, and hotels. Apartments and offices constitute the major portion of this index at more than 50% weighting.

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