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A Study on Information Spillover Effects between the Korean, U. S. and Japanese Housing Markets

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Abstract. Through the recent global financial crisis, there is emerging recognition that a country's housing market shock can affect other countries' housing market volatility. Therefore, this study aims to verify whether price and volatility spillover effects exist between the Korean, U.S., and Japanese housing markets. To this end, this study analyzed the impacts of shocks that occurred in each country on other countries' housing markets by estimating each country's returns model of the housing price index from June 1993 until December 2021 using the EGARCH model. The analysis results are as follows: First, the positive asymmetric volatility spillover effect existed due to news shock in the Korean housing market. Second, the negative asymmetric volatility spillover effect was observed due to news shock in the U.S. housing market. Therefore, a leverage effect revealed in the stock market was found. Third, although no asymmetric volatility spillover effect existed between the U.S. and Japanese housing markets, the price spillover effect existed. It was confirmed that information spillover effects were limited in the enormous trends of opening and globalization in the housing market due to real estate's regional characteristics, unlike the stock market.

Keywords: Housing markets, information, spillover effects, asymmetric volatility, EGARCH model

1. Introduction

Diversities of investment information are delivered to the housing market due to synchronization of the international capital market, high speed information and communications, overseas real estate investment expansion of multinational real estate companies, and each government's policy support consolidation for attracting investments; consequently, ripple effects on each country's housing market are gradually accelerating. In particular, hedge funds and global investment banks are increasing the ratio of capital inflow and outflow in the international housing market to diversify risks in the traditional financial products and obtain short-term profit from the valuation. Recognition that price and volatility spillover effects may exist in the housing market, like the international financial market, is emerging. Real estate price volatility has been increasing through the global financial crisis according to the subprime mortgage crisis in the U.S. in 2008. Therefore, analyzing its impacts gains attention as a critical research task to dynamically understand and stably manage the housing market.

Volatility indicates uncertainty or risk in financial economics, and it is managed as variance statistically. Spillover of volatility means risks are shifted from one country's housing market into another country's housing market, and the U.S. housing market risks can play a pivotal role in the Korean housing market's risk measurement and hedge strategy. Even though many studies on information spillover effects in the international financial market are carried out, it is not easy to find studies on such effects in the Korean, U.S., and Japanese housing markets; in fact, no study on the asymmetric volatility spillover effect between those countries can be found. Most of the existing studies have mainly conducted research on the housing market within the category of a country. In particular, there are no studies on the existence of an asymmetrical volatility spillover effect between the Korean, U.S., and Japanese housing markets.

Therefore, the purpose of this study is to provide policy implications for stabilizing the housing market by empirically analyzing whether there are price and volatility transfer effects between the Korean, U.S., and Japanese housing markets. The data used in the study were the housing sale price index of each country, and an EGARCH model that can effectively capture asymmetric responses to information on housing price volatility was used. The differentiation of this study is to compare and analyze whether or not the information transfer effect exists by expanding the subject of the study internationally from the region of a country. The differentiation of this study is to compare and analyze whether or not the information transfer effect exists by expanding the subject of the study internationally from the region of a country. In addition, it is to confirm whether the information transfer effect exists asymmetrically by country with EGARCH model.

Initial stage studies on volatility spillover effects have been mainly performed by focusing on correlations between returns of stocks. Therefore, there are few studies on volatility spillover effects targeting the housing market. Since the 1980s, as studies on the spillover effects based on the ARCH models have been actively carried out, French et al., (1987) presented that volatility can increase when the possibility of public-private information arrives in the asset market increases. Thus, it affects investment decision-making. Although Hamao et al., (1990) analyzed price and volatility spillover effects using the stock indices of New York, London, and Tokyo, they did not present a significant result. However, Engle et al., (1993) identified significant returns volatility spillover effects, unlike the result of Hamao et al., (1990). Engle and Kroner (1995) contributed to grasping the structure of conditional heteroscedasticity of multivariate data using the GARCH model. Bekaert et al., (1997) presented a study result that emerging countries' capital markets can bring a high correlation with developed countries' capital markets in terms of liberalization of the capital market, but that there can be a limitation in leading volatility of emerging countries' capital markets. Dolde and Tirtiroglue[6] analyzed and presented 36 key factors affecting the volatility of housing prices using the GARCH model. Most volatility factors are regional factors, but the volatility of economic state, national and regional income growth, inflation, and interest rate are national factors. They presented a conflicting result from Bekaert et al., (1997) by reporting a study result that regional housing price volatility spreads to regions but does not decrease. Evenson (2003) asserted that the factors affecting housing price volatility in 47 cities in the U.S. affect the short- and long-term housing supply elasticity, including population, land area, economic growth, and housing policy incentives. Miller et al., (2006) analyzed the dynamic relationship with detached house value volatility using the VAR model's housing price indices of 277 metropolitan statistical areas. According to the analysis result, detached house value volatility is greatly affected by exogenous factors such as population growth, and improvement of income increase rate per capita rather works as a factor reducing volatility. Tsal et al., (2009) presented a significant result of housing price volatility and asymmetry using the GJR-GARCH model targeting the British housing market. Willcocks (2010) asserted that ARCH effects in seven regions and asymmetric volatility in six regions existed due to estimating price volatility existence in 13 regions in the U.K. using the GARCH model and EGARCH model. Choi et al., (2013) analyzed the volatility spillover effect by targeting apartment sales and rental markets in nine major regions, including Seoul. The analysis revealed that ARCH and GARCH effects existed in the nine regions and asymmetric effects in the apartment sales market using the EGARCH model. Fairchild et al., (2015) asserted that risk premium in the housing market was much more important than regional growth rate or interest rate in terms of what critically affects housing price volatility. Tian et al., (2009) reported that short-term external capital inflow increased housing market volatility in China.

Meanwhile, Chun (2015) estimated the apartment sales price, rental price volatility, and spillover effect in Gangnam and Gangbuk in Seoul using the GARCH and EGARCH models. As a result, they revealed that asymmetric effects existed in the apartment sales and rental prices. As a result of Choi's empirical analysis of price volatility between housing sales prices and rental prices in Gangnam and Gangbuk in Seoul using the EGARCH model, the existence of price mobility between these districts was revealed (Choi 2020).

2. Analysis Method

2.1. Data

The Kookmin Bank apartment price index released monthly by Kookmin Bank was used for data representing the Korean housing market. The housing price index monthly announced by the U.S. Federal Housing Finance Agency (FHFA) was used for the U.S.single family sale price index. The housing price index released monthly by the Japan Real Estate Institute (JREI) was used for the Japanese condominium sale price index. All these were used through seasonal adjustment. The analysis period was June 1993 until December 2021, when the Japanese housing price data obtainment was possible. Fig. 1 shows the housing price trends in Korea, the U.S., and Japan.

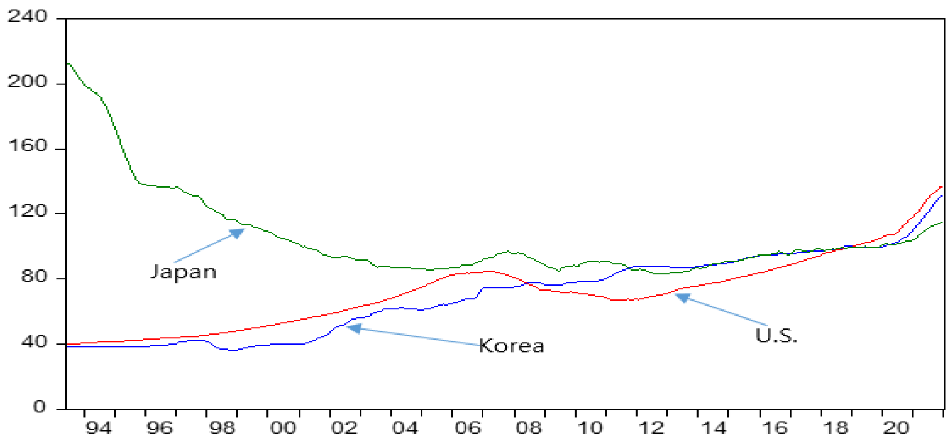

Fig. 1: Trends of housing prices in Korea, the U.S., and Japan.

Table 1 shows the basic statistics on housing price fluctuation rate and unit root test. Skewness showed bias distribution in a positive direction in Korea and a negative direction in the U.S. and Japan. Kurtosis showed leptokurtic distribution compared with normal distribution in all Korea, the U.S. and Japan. The null hypothesis that skewness, kurtosis, and Jarque-Bera statistics show normal distribution at a 1% significance level is rejected. Therefore, there is a need to apply a heteroscedasticity-based ARCH model. The basic assumption of time series data premises stationary data, so this study used augmented Dickey-Fuller (ADF) (Dickey et al., 1979) and

Phillips-Perron (PP) (Phillips et al., 1989) test methods generally used to test stationary data attributes. The test results are shown in Table 1. As for housing sales price fluctuation rate, this study conducted a unit root test for lag 1, including constant term targeting time series differenced after taking natural logarithm on the price index. In the case of differenced housing price time series, the null hypothesis was rejected at a 1% significance level, so it was identified that all were stationary time series data.

Table 1: Basic statistics and unit root test results of housing price.

		Korea		U.S..		Japan	
Mean		0.3572		0.3613		-0.1783	
Std. Dev.		0.7400		0.4996		0.7883	
Skewness		0.6483		-0.8223		-0.5846	
Kurtosis		9.6675		5.3404		4.0497	
Jarque-Bera		657.46		116.60		35.18	
Probability		(0.0000)		(0.0000)		(0.0000)	
Unit Root Test		Level variable	Differential variable	Level variable	Differential variable	Level variable	Differential variable
	ADF	1.3000	-5.5479	1.0030	-2.8856	-5.6138	-2.9012
	PP	1.8711	-5.4022	2.5526	-5.2463	-6.6029	-7.9354

Note 1) ( ) indicates a 1% significance level that may reject the null hypothesis of Jarque-Bera statistics.
2) ADF, PP: Each threshold at a 1% significance level when including the constant term: -3.46

Fig. 2 shows dynamic volatility trends in the housing price fluctuation rate. In the housing price fluctuation rates of Korea, the U.S., and Japan, volatility clustering that short volatility continued to some degree after considerable volatility continued some degree was revealed.

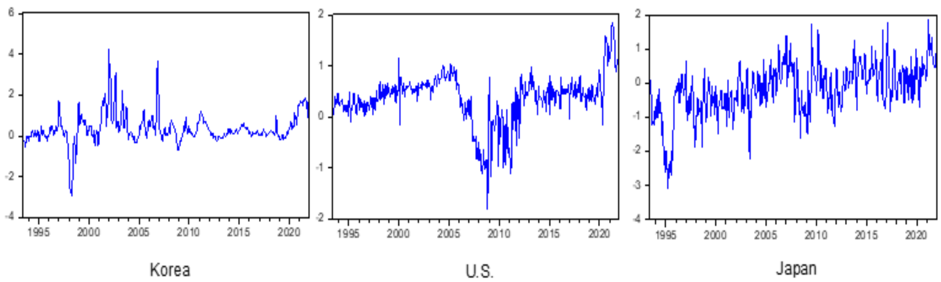

Fig. 2: Housing price fluctuation rates in Korea, the U.S., and Japan.

To verify whether the GARCH model is suitable for analyzing housing price fluctuation rate, Ljung-Box Q statistics tests were carried out in lag 6 and lag 12 regarding fluctuation rate and square of fluctuation rate, and the results are shown in

Table 2. According to the rest result, the p values of Q statistics concerning the housing price fluctuation rate and the square of the fluctuation rate in lag 6 and lag 12 were all zero (0), so the null hypothesis was rejected. This means the existence of autocorrelation, which indicates the existence of heteroscedasticity according to Bollerslev and Hsieh (Bollerslev 1986; Hsieh 1989). The OLS estimation assuming that residual variance is constant does not have efficiency, and the application of the ARCH models is suitable. LM test of Engle was performed to examine whether regression residual's second moment is correlated (Engle 1982). According to the analysis result, it was found that the ARCH effect existed in all housing price time series in Korea, the U.S., and Japan, and Table 2 shows its existence. To test the asymmetry of volatility, the asymmetric test of Engle and Ng was carried out, and Table 2 shows the test results (Ng et al., 1993). The asymmetry of volatility consists of a sign bias test (SB), a negative size bias test (NSB), a positive size bias test (PSB), and a joint test. The original regression equation is as follows: $y_t = \beta' Z_t + \varepsilon_t$. If ${S_{t-1}}^-$ is $e_{t-1} \langle 0,$ it is a dummy of 1. If not, it is a dummy of 0. Finally, ${S_{t-1}}^+ = 1 - {S_{t-1}}^-$.

$$\text{SB: } {u_t}^2 = a + b{S_{t-1}}^- + \beta' {Z_t}^* + e_t, \quad H_0 : b = \beta = 0$$

$$\text{NSB: } {u_t}^2 = a + b{S_{t-1}}^- e_{t-1} + \beta' Z^* + e_{t,} \ H_0 : b = \beta = 0$$

$$\text{PSB: } {u_t}^2 = a + b{S_{t-1}}^+ e_{t-1} + \beta' {Z_t}^* + e_{t,} \ H_0 : b = \beta = 0$$

$$\text{JOINT: } {u_t}^2 = a + b_1{S_{t-1}}^- + b_2{S_{t-1}}^- e_{t-1} + b_3{S_{t-1}}^+ e_{t-1} + \beta' {Z_t}^* + e_{t,}$$
$$H_0 = b_1 = b_2 = b_3 = \beta = 0$$

In the asymmetry test results in Table 2, NSB, PSB, and Joint existed in the Korean and U.S. housing price time series, so the EGARCH model seems to apply, but the bias was not evident in Japan. The results are compared in Japan, where asymmetry is unclear, applying the EGARCH model like in Korea and the U.S.

Table 2: Autocorrelation and asymmetric test statistics.

	Autocorrelation				ARCH Effect		Asymmetry			
	Q(6)	Q(12)	$Q^2(6)$	$Q^2(12)$	LM (3)X^2	LM (6)X^2	SB(t)	NSB (t)	PSB (t)	JOINT (F)

Korea	557.0 (0.000)	623.32 (0.000)	189.0 (0.000)	239.9 (0.000)	60.505	31.386	-0.414*	-1.934	5.077	11.662
U.S.	1028.5 (0.000)	1680.3 (0.000)	608.3 (0.000)	793.1 (0.000)	82.139	46.775	0.004*	-5.164	3.310	13.284
Japan	527.2 (0.000)	758.7 (0.000)	579.3 (0.000)	625.1 (0.000)	85.248	43.335	-0.583*	-1.222	0.239*	0.517*

Note: 1) Q(6) and Q(12) indicate the Ljung-Box statistics of the fluctuation rate, and $Q^2(6)$ and $Q^2(12)$ square of fluctuation rate in lag 6 and lag 12.
*2) ( ) indicates p-value. *: figurative at 10% significance level.*

2.2. Models

Spillover effects can be divided into a price spillover effect and a volatility spillover effect in the housing market, as shown in the financial market. Volatility spillover effects can be explained as volatility clustering and asymmetric volatility. Volatility clustering refers to a phenomenon in which small volatility continues to some degree after significant volatility continues to some degree in the volatility of returns (volatility, conditional variance) in the financial time series. The asymmetric spillover effect of volatility refers to a phenomenon the Korean stock price index falls more than α%, not at the same level of α%, as the U.S. stock price index rises α%. Generally, the stock price index responds to bad news (information) more than good news (information). In such a case, volatility appears asymmetrically.

Nelson (1991) presented the EGARCH model suitable for the asymmetric spillover effect analysis. This study applied a properly-revised EGARCH model. The return of housing price ($R_{i,t}$) is calculated with continuous compound interest return as shown in Equation (1) using the closing housing price in the previous month P_{t-1} and the closing housing price in the current month P_t. Ω_{t-1} is a set of information provided in the period of t-1. Under the provided information set, $u_{i,t}$ indicates the mean of i market in t period, $\sigma_{i,t}{}^2$ indicates i market variance in t period, and $\varepsilon_{i,t}$ indicates shock factors and $z_{i,t}$ indicates standardization innovation in t period as follows:

$$R_{i,t} = 100\ln\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

$$\varepsilon_{i,t} = R_{i,t} - u_{i,t} \tag{2}$$

$$z_{i,t} = \varepsilon_{i,t}\,\frac{}{\sigma_{i,t}} \tag{3}$$

Under the assumption, the bivariate EGARCH model used in this study can be expressed as a conditional mean equation and a conditional variance equation, as shown in Equations (4) to (8). Also, i=1 indicates the domestic housing market (overseas housing market), and i=2 indicates the overseas housing market (domestic housing market).

$$R_{i,t} = \beta_{i,t} + \sum_{j=1}^{2} \beta_{i,j}\, \varepsilon_{j,t-1} + \varepsilon_{i,t} \quad (4)$$

$$z_{i,t} \,|\Omega_{t-1} \sim N(0,1) \quad (5)$$

$$\sigma_{i,t}{}^2 = \exp[\alpha_{i,0} + \textstyle\sum_{j=1}^{2} \alpha_{i,j}\, f_j(z_{j,t-1}) + \gamma_i \ln(\sigma_{i,t-1}{}^2) \quad (6)$$

$$f_j(z_{j,t-1}) = (|z_{j,t-1}| - E(|z_{j,t-1}|) + \delta_j z_{j,t-1}) \quad (7)$$

Where $E(z_{j,t}) = \sqrt{\frac{2}{\pi}}$ if $z_{j,t}\,|\Omega_{j,t-1} \sim N(0,1)$

$$\ln f(\varepsilon_{i,1}, \cdots, \varepsilon_{i,T}) = -\frac{T}{2}\ln(2\pi) - \frac{1}{2}\textstyle\sum_{t=1}^{T} \ln \sigma_{i,t}{}^2 - \frac{1}{2}\sum_{t=1}^{T} \ln \frac{\varepsilon_{i,t}{}^2}{\sigma_{i,t}{}^2} \quad (8)$$

Equations (4) and (5) indicate the conditional mean equation and standardized error term on each market return. Each market's conditional mean was indicated with a Vector Moving Average (VMA) model affected by the past residual in the market (if j=1) and in the other market (if j=2). The goodness of fit of Equation (4) is carried out through the Ljung-Box test. In Equation (5), the standardized error term shows conditional normal distribution under the past information set until the t-1 period. Equation (6) shows a variance equation. Conditional variance in a market is affected by a combination of its own and other markets' standardized past residuals and their past conditional variance. Persistency of volatility is indicted as γ. If $\gamma \prec 1$, nonconditional variance exists. If $\gamma = 1$, nonconditional variance does not exist, and first-order integrated time series process I (1) is complied with. Equation (7) indicates ARCH (autoregressive conditional heteroskedasticity) effects. In Equation (7), $|z_{j,t-1}| - E(|z_{j,t-1}|)$ indicates the size of ARCH effects, and $\delta_{j,} z_{j,t-1}$ indicates a sign effect. The sign effect indicates asymmetric effect size, meaning a leverage effect. The size of the leverage effect is expressed in the ratio of $|-1 + \delta_j| \,/\, |1 + \delta_j|$, and the size means how greatly the negative (positive) shock increases volatility compared to the positive (negative) shock. The sign effect can be indicated in the five following cases depending on the value of δ_j.

(1) $If\ \delta_j = 0$: The negative shock brings the exact size of volatility change as the positive shock.

(2) $If\ -1 \prec \delta_j \prec 0$: The negative shock increases volatility more than the positive shock.

(3) If $\delta_j \prec -1$: The negative shock increases volatility, but the positive shock reduces volatility less than the negative shock.

(4) $If\ 0 \prec \delta_j \prec 1$: The positive shock increases volatility more than the negative shock.

(5) If $\delta_j \succ 1$: The positive shock increases volatility, but the negative shock reduces volatility less than the positive shock.

Equation (8) indicates the log-likelihood function of GARCH (1, 1). The log-likelihood function calculates the maximum likelihood estimator using generalized numeric value optimization such as Newton, BHHH, BFGS, Marquardt, and DFP. This study uses a generalized Marquardt algorithm rather than the Newton-Raphson algorithm. Based on the bivariate EGARCH model in Equations (4) to (8), one may assume that there are no price and volatility spillover effects from the U.S. (or Japanese) housing market to the Korean housing market when an analysis of spillover effects from the U.S. (or Japanese) housing market to the Korean housing market is carried out. In the opposite case, one may assume that there are no price and volatility spillover effects. Under the assumptions, this study set the price and volatility spillover estimation equations with the models in Equations (9) to (14) and used them in the empirical analysis.

$$R_{1,t} = \beta_{1,0} + \beta_{1,1}\varepsilon_{1,t-1} + \varepsilon_{1,t} \tag{9}$$

$$R_{2,t} = \beta_{2,0} + \beta_{2,1}\varepsilon_{1,t-1} + \beta_{2,2}\varepsilon_{2,t-1} + \varepsilon_{2,t} \tag{10}$$

$$\sigma_{1,t}{}^2 = \exp\left[\alpha_{1,0} + \alpha_{1,1}f_1\left(z_{1,t-1}\right) + \gamma_1 \ln\left(\sigma_{1,t-1}{}^2\right)\right] \tag{11}$$

$$\sigma_{2,t}{}^2 = \exp\left[\alpha_{2,0} + \alpha_{2,1}f_1\left(z_{1,t-1}\right) + \alpha_{2,2}f_2\left(z_{2,t-1}\right) + \gamma_2 \ln\left(\sigma_{2,t-1}{}^2\right)\right] \tag{12}$$

$$f_1\left(z_{1,t-1}\right) = \left(\left|z_{1,t-1}\right| - E\left(\left|z_{1,t-1}\right|\right) + \delta_1 z_{1,t-1}\right) \tag{13}$$

$$f_2\left(z_{2,t-1}\right) = \left(\left|z_{2,t-1}\right| - E\left(\left|z_{2,t-1}\right|\right) + \delta_2 z_{2,t-1}\right) \tag{14}$$

3. Analysis Results

3.1. Spillover effect analysis in the Korean and U. S. housing markets

Table 3 shows a spillover effect analysis from the Korean housing market to the U.S. housing market and vice versa. Since the coefficient of $\beta_{2,1}$ indicates that the price spillover effect was insignificant, no price spillover effect from the Korean to the U.S. housing markets seems to exist. Since the coefficients of $\alpha_{2,1}$ and δ_1 indicating volatility spillover effects were insignificant, no volatility spillover effect from the Korean to the U.S. housing markets seems to exist. In the Korean housing market, the coefficient of $\alpha_{1,1}$ was significant at 1% significance level, and the coefficient of δ_1 was positive and significant at 5% significance level. Although the coefficient of $\alpha_{2,2}$ was significant at 1% significance level in the U.S. housing market, the coefficient of δ_2 was insignificant. This means that positive and asymmetric volatility spillover effects are revealed due to news shock in the Korean housing market, but no asymmetric volatility spillover effect is revealed in the U.S. housing market.

Table 3: Analysis results of housing market spillover effects in Korea and the U.S.

	Spillover effects from the Korean housing market to the U.S. housing market		Spillover effects from the U.S. housing market to the Korean housing market	
	Coefficient values	Z-statistics	Coefficient values	Z-statistics
$\beta_{1,0}$	0.2515	2.4114***	0.4251	8.8649***
$\beta_{1,1}$	0.8463	29.4560***	0.7125	17.5101***
$\alpha_{1,0}$	-0.6803	-6.5747***	-0.3190	-7.0183***
$\alpha_{1,1}$	0.6001	7.2237***	0.2910	6.5384***
δ_1	0.1036	2.1465**	-0.0472	-1.4146
γ_1	0.8850	40.2855***	0.9613	68.0977***
$\beta_{2,0}$	0.4087	8.8112***	0.2148	2.1876**
$\beta_{2,1}$	0.0249	0.8889	0.0341	0.8311
$\beta_{2,2}$	0.7132	17.2328***	0.8416	28.9374***
$\alpha_{2,0}$	-0.3408	-7.4577***	-0.6323	-6.0673***
$\alpha_{2,1}$	-0.0582	-1.0369	-0.5002	-2.3830***
$\alpha_{2,2}$	0.2916	6.2759***	0.5823	6.9573***
δ_2	-0.0553	-1.5878	0.1082	2.2698**
γ_2	0.9468	62.1953***	0.8777	36.8097***
Statistics of Standardized Residual				
	Korea	U.S.	U.S.	Korea
	Housing Returns	Housing Returns	Housing Returns	Housing Returns
Mean	0.0555	-0.0198	-0.0228	0.0684
SD	0.9996	0.9997	0.9988	0.9986
Skewness	0.8516	-0.3571	-0.3372	0.7301
Kurtosis	6.8303	4.0191	4.1321	6.2928
LB (12)	8.11	89.36	89.84	7.8
	(-0.776)	(0.000)	(0.000)	(0.800)
LB2 (12)	2.288	17.48	18.67	2.93
	(0.999)	(0.132)	(0.097)	(0.996)

*Note: 1) * indicates 10% (1.64) significance level. ** indicates 5% (1.96) significance level. *** indicates 1% (2.58) significance level.*
2) ( ) indicates p-value.

One may look at the spillover effect from the U.S. housing marking to the Korean housing market. Because the coefficient of $\beta_{2,1}$ indicates that the price spillover effect is insignificant, no price spillover effect from the U.S. housing market to the Korean housing market seems to exist. Since the coefficient of $\alpha_{2,1}$ indicated that the volatility spillover effect was significant, the coefficient of δ_1 was insignificant, so no volatility spillover effect from the U.S. housing market to the Korean housing market seems to exist. Although the coefficient of $\alpha_{1,1}$ was significant at 1% significance level, the coefficient of δ_1 was insignificant in the U.S. housing market. In the Korean housing market, the coefficient of $\alpha_{2,2}$ was significant at 1% significance level, and the coefficient of δ_2 was significant at 5% significance level. This means that news shock reveals no asymmetric volatility spillover effect in the U.S. housing market, although it is revealed in the Korean housing market. Consequently, no price and volatility spillover effects existed in the Korean and U.S. housing markets, but positive and asymmetric volatility spillover effects existed in the Korean housing market due to news shock.

3.2. Spillover effect analysis in the Korean and Japanese housing markets

Table 4 shows the results of the spillover effect analysis from the Korean housing market to the Japanese housing market and vice versa. One may examine the spillover effect from the Korean housing market to the Japanese market. The coefficient of $\beta_{2,1}$ indicates that the price spillover effect was insignificant, so no such effect from the Korean housing market to the Japanese housing market seems to exist. Since the coefficients of $\alpha_{2,1}$ and δ_1 indicating volatility spillover effect were insignificant, no volatility spillover effect from the Korean housing market to the Japanese housing market seems to exist. In the Korean housing market, the coefficient of $\alpha_{1,1}$ was significant at 1% significance level, and the coefficient of δ_1 was positive and significant at 5% significance level. In the Japanese housing market, the coefficients of $\alpha_{2,2}$and δ_2 were insignificant. This means that positive and asymmetric volatility spillover effect is revealed in the Korean housing market but not in the Japanese housing market.

Table 4: Spillover effect analysis results in the Korean and Japanese housing markets.

	Spillover Effects from the Korean Housing Market to the Japanese Housing Market		Spillover Effects from the Japanese Housing Market to the Korean Housing Market	
	Coefficient Value	Z-statistics	Coefficient Value	Z-statistics
$\beta_{1,0}$	0.2515	2.4114***	-0.1486	-1.8317*
$\beta_{1,1}$	0.8463	29.4560***	0.5785	12.9149***
$\alpha_{1,0}$	-0.6803	-6.5747***	-0.3190	-0.8633
$\alpha_{1,1}$	0.6001	7.2237***	0.0776	0.7216
δ_1	0.1036	2.1465**	-0.0696	-0.8337
γ_1	0.8850	40.2855***	0.7339	2.1543**
$\beta_{2,0}$	-0.1529	-1.6317*	0.2510	2.2888**
$\beta_{2,1}$	-0.0152	-0.1779	-0.0380	-1.4827
$\beta_{2,2}$	0.5908	12.7452***	0.8567	31.6954***
$\alpha_{2,0}$	-0.3498	-0.9971	-0.8879	-3.2790***
$\alpha_{2,1}$	0.0453	0.4247	0.4036	0.6814
$\alpha_{2,2}$	0.0946	0.8054	0.6410	7.0728***
δ_2	-0.0701	-0.8899	0.1397	2.6307***
γ_2	0.7267	2.4088***	0.8760	36.5567***
Statistics of Standardized Residuals				
	Korea	Japan	Japan	Korea
	Housing Returns	Housing Returns	Housing Returns	Housing Returns
Mean	0.0555	-0.0016	-0.0079	0.0571
SD	0.9996	1.0015	1.0019	0.9996
Skewness	0.8516	-0.0110	0.0301	0.8271
Kurtosis	6.8303	3.3615	3.3597	6.6596
LB (12)	8.11	113.23	113.16	8.21
	(-0.776)	(0.000)	(0.000)	(0.768)
LB^2 (12)	2.288	8.55	7.94	2.52
	(0.999)	(0.741)	(0.789)	(0.998)

*Note: 1) * indicates 10% (1.64) significance level. ** indicates 5% (1.96) significance level. *** indicates 1% (2.58) significance level.*
2) ( ) indicates p-value.

One may examine the spillover effect from the Japanese housing market to the Korean market. The coefficient of β2,1 indicates that the price spillover effect was insignificant, so no spillover effect exists from the Japanese housing market to the

Korean housing market. Since the coefficients of α2,1 and δ1 indicating volatility spillover effect were insignificant, no volatility spillover effect seems to exist in the Japanese housing market to the Korean housing market. In the Japanese housing market, the coefficients of α1,1 and δ1 were insignificant. In the Korean housing market, the coefficient of α2,2 was significant at 1% significance level, and the coefficient of δ2 was significant at 1% significance level. This means that asymmetric volatility spillover effects due to news shock are not revealed in the Japanese housing market, but the effects appear in the Korean housing market. Although price and volatility spillover effects did not exist in the Korean and Japanese housing markets, the positive and asymmetric volatility spillover effect existed in the Korean housing market by news shock.

3.3. Spillover effect analysis in the U.S. and Japanese housing markets

Table 5 shows a spillover effect analysis from the U.S. housing market to the Japanese housing market and vice versa. One may examine spillover effects from the U.S. housing market to the Japanese market. The coefficient of $\beta_{2,1}$ indicates that the price spillover effect was significant at 10% significance level, and thus the price spillover effect from the U.S. housing market to the Japanese housing market seems to exist. Since coefficients of $\alpha_{2,1}$ and δ_1 indicate that volatility spillover effects are insignificant, no volatility spillover effect from the U.S. housing market to the Japanese housing market seems to exist. In the U.S. housing market, the coefficient of $\alpha_{1,1}$ was significant at 1% significance level, and the coefficient of δ_1 was insignificant. In the Japanese housing market, the coefficients of $\alpha_{2,2}$ and δ_2 were insignificant. This means that no asymmetric volatility spillover effect exists in the U.S. and Japanese housing markets by news shock.

Table 5: Spillover effect analysis results in the U.S. and Japanese housing markets.

	Spillover Effects from the U.S. Housing Market on the Japanese Housing Market		Spillover Effects from the Japanese Housing Market on the U.S. Housing Market	
	Coefficient Value	Z-statistics	Coefficient Value	Z-statistics
$\beta_{1,0}$	0.4251	8.8649***	-0.1486	-1.8317*
$\beta_{1,1}$	0.7125	17.5101***	0.5785	12.9149***
$\alpha_{1,0}$	-0.3190	-7.0183***	-0.3190	-0.8633
$\alpha_{1,1}$	0.2910	6.5384***	0.0776	0.7216
δ_1	-0.0472	-1.4146	-0.0696	-0.8337
γ_1	0.9613	68.0977***	0.7339	2.1543**
$\beta_{2,0}$	-0.2415	-2.6682***	0.4381	10.1765***
$\beta_{2,1}$	0.1864	1.8583*	0.0519	2.1444**
$\beta_{2,2}$	0.5855	11.4546***	0.6984	16.3787***
$\alpha_{2,0}$	-0.5093	-1.0528	-0.2266	-2.2572**
$\alpha_{2,1}$	0.3582	0.8384	-0.1808	-0.6829
$\alpha_{2,2}$	0.1309	0.9976	0.2473	5.3954***
δ_2	-0.0601	-0.7366	-0.0639	-1.8446*
γ_2	0.6264	1.5973	0.9566	68.8973***
Statistics of Standardized Residual				
	U.S. Housing Returns	Japan Housing Returns	Japan Housing Returns	U.S Housing Returns
Mean	-0.0228	0.004	-0.0079	-0.251
SD	0.9988	1.0017	1.0019	1.001
Skewness	-0.3372	-0.0680	0.0301	-0.4011
Kurtosis	4.1321	3.3043	3.3597	3.9924
LB (12)	89.84 (0.000)	109.24 (0.000)	113.16 (0.000)	91.64 (0.000)
LB^2 (12)	18.67 (0.097)	7.27 (0.839)	7.94 (0.789)	17.56 (0.129)

*Note: 1) * indicates 10% (1.64) significance level. ** indicates 5% (1.96) significance level. *** indicates 1% (2.58) significance level.*
2) ( ) indicates p-value.

One may look at spillover effects from the Japanese housing market to the U.S. housing market. Because the coefficient of $\beta_{2,1}$ indicates that the price spillover effect was significant at 1% significance level, the price spillover effect from the Japanese housing market to the U.S. housing market seems to exist. Since the coefficients of $\alpha_{2,1}$ and δ_1 indicating volatility spillover effect were insignificant, no volatility spillover effect from the Japanese housing market to the U.S. housing market seems to exist. In the Japanese housing market, the coefficients of $\alpha_{1,1}$ and δ_1 were insignificant. In the U.S. housing market, the coefficient of $\alpha_{2,2}$ was significant at 1% significance level, and the coefficient of δ_2 was significant at 10% significance level. All of these mean that news shock reveals no asymmetric volatility spillover effect in the Japanese housing market but that negative and asymmetric volatility spillover effect exists in the U.S. housing market. Although the price spillover effect existed between the Japanese and U.S. housing markets, no volatility spillover effect existed.

3.4. Leverage effect size by standardized past error term

To examine asymmetric spillover effect size concretely, it was calculated as shown in [Table 6]. In the Korean housing market, δ_j was between 0 and 1, so the positive shock by the standardized past error term was larger by 0.8122 times than the negative shock. In the U.S. housing market, δ_j was between -1 and 0, so the negative shock by the standardized past error term was larger by 1.0990 times than the positive shock in terms of the impacts. In the Japanese housing market, δ_j was between -1 and 0, and the impact of the standardized past error term was 1.1396 times larger in the negative shock than in the positive shock. However, the coefficients of $\alpha_{j,j,}$ and δ_j were insignificant, so the leverage effect was unclear. Consequently, the leverage effect became more prominent in the Korean housing market because of positive rather than negative shock.

Table 6: Leverage effect size affected by standardized past error term

	Korea	U.S.	Japan
Leverage Effect	0.8122**	1.0990*	1.1396

Note 1) In case only $\alpha_{j,j}$ is significant at 5% (*): If affected by the standardized past residual.

2) In case 5 $\alpha_{j,j}$ and δ_j are significant at 5% (**): If asymmetrically affected by the standardized past residual

3.5. Volatility spillover effects between the Korean, U.S., and Japanese housing markets

The impacts of shock in the Korean (U.S.) housing market on the conditional variance of the U.S. (Korean) housing market can be expressed using $\alpha_{2,1}$ and δ_1 in Equations (12) and (13). The volatility spillover effect was calculated using an equation presented by Koutmos and Booth (1995). The impacts of +5% and -5% shocks of the Korean (U.S.) housing market on the conditional variance in the U.S. (Korean) housing market are calculated as follows, as shown in Table 7. To apply the calculation method, an assumption that external shock is 0 and an assumption that γ_2 indicating persistence should come close to 1 should be met.

$$5\% \times \alpha_{2,1} \times (1 + \delta_1) \quad (15)$$

$$5\% \times \alpha_{2,1} \times (-1 + \delta_1) \quad (16)$$

Table 7 reveals the volatility spillover effects of the positive and negative shocks in the Korean (U.S.) housing market on the U.S. (Korean) housing market. The volatility spillover effects of positive and negative shocks in the Korean housing market on the U.S. housing market did not exist. Compared to the positive shock in the U.S. housing market, the negative shock was estimated to have higher volatility spillover effects on the Korean housing market.

Table 7: Volatility spillover Effects of ±5% shocks in the Korean (U.S.) housing market on the U.S. (Korean) housing market.

	+5% Shock	-5% Shock
Korean Housing Market	2.3829*	2.6190*
U.S. Housing Market	0.3211	0.2608

Note 1) In case only volatility spillover effects at 5% are significant (*)
2) In case asymmetric volatility spillover effects at 5% are significant (**)

Table 8 shows the volatility spillover effects of the positive and negative shocks in the Korean (Japanese) housing market on the Japanese (Korean) housing market. The volatility spillover effect and asymmetric spillover effect of the positive and negative shocks in the Korean and Japanese housing markets on the Japanese and Korean housing markets were insignificant.

Table 8: Volatility spillover effects of ±5% Shocks in the Korean (Japanese) housing market on the Japanese (Korean) housing market.

	+5% Shock	-5% Shock
Korean housing market	1.8775	2.1584
Japanese housing market	5.7445	0.2030

Note 1) In case only volatility spillover effects are significant at 5% (*)
2) In case asymmetric spillover effects are significant at 5% (**)

Table 9 shows the volatility spillover effects of the positive and negative shocks in the U.S. (Japanese) housing market on the Japanese (U.S.) housing market. The volatility spillover effect and asymmetric spillover effect of the positive and negative shocks in the U.S. and Japanese housing markets on the Japanese and U.S. housing markets were insignificant, respectively.

Table 9: Volatility spillover effects of ±5% shocks in the U.S. (Japanese) housing market on the Japanese (U.S.) housing market.

	+5% Shock	-5% Shock
U.S. Housing Market	0.8410	0.9669
Japanese Housing Market	1.7064	1.8755

Noe: 1) In case only volatility spillover effects at 5% are significant (*)
2) In case asymmetric volatility spillover effects at 5% are significant (**)

4. Discussion

To verify whether price and volatility spillover effects exist between the Korean, U.S., and Japanese housing markets, this study analyzed each country's housing price index with the EGARCH model from June 1993 until December 2021. According to the analysis results, the positive and asymmetric volatility spillover effects existed in the Korean housing market by news shock. This means that volatility can be bigger by positive shock than negative shock in the housing market and shows that housing as an asset with profitability and stability can be a subject of speculation. Second, a negative and asymmetric spillover effect by news shock was observed in the U.S. housing market, and a leverage effect often revealed in the stock market was also revealed. Third, although no asymmetric volatility spillover effect existed between the U.S. and Japanese housing markets, the price spillover effect existed. This means that the Japanese (U.S.) housing market can be predicted by observing the U.S. (Japanese) housing market. Fourth, price and volatility spillover effects did not exist in the Japanese housing market. Through the analysis above, no information spillover effect could not be observed between the three countries except the price spillover effect between the U.S. and Japanese housing markets. Consequently, it was confirmed that information spillover effects in the vast trends of opening and globalization were limitedly revealed due to the unique regional characteristics of real estate, different from the stock markets.

5. Conclusions

From an aspect that the real estate market's internationalization and opening are expanded, information spillover effects between countries were limitedly observed through this study. In addition, it was found that the real estate market had regional characteristics. Therefore, differentiated accessibility by region is required for stabilizing the housing market and strategic investment. The study result is expected to significantly enhance the understanding of dynamic real estate markets for hedge strategy investors seeking diversification by expanding global real estate investments and policymakers who pursue managing local housing markets stably. Nonetheless, this study was based on univariate research, and therefore there are limitations in generalization for the international real estate markets. A further study using a more sophisticated and multivariate model remains a follow-up research task.

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