7. RISK TRANSMISSION AND CONTAGION IN THE EQUITY MARKETS: INTERNATIONAL EVIDENCE FROM THE GLOBAL FINANCIAL CRISIS

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Abstract

This study examines the time-varying volatility spillover mechanisms between the US (S&P 500) and the world's largest stock markets, including those of the G20 countries, along with some selected European equity exchanges between 1994 and 2014. In the context of the empirical study, we adopt a multivariate BEKK-GARCH model with its asymmetric generalization. Overall, our results suggest that there is a significant shock and volatility transmission from the S&P 500 to the other stock markets while the opposite (from the others to the US) is also observed for some market-pairs under investigation. Furthermore, we analyze whether market volatilities and time-varying correlations significantly change during the different phases of the 2007-2009 global financial crisis or not. The linear regression analyses with the dummy indicators suggest heightened variances and correlations, which signifies the crisis spillover and contagion.

Keywords: volatility spillover, shock transmission, contagion, emerging markets, ABEKK-GARCH model

JEL Classification: G01, G11, G15.

1. Introduction

The technological advancements, the proliferation in the global trading activities, the deregulation and the liberalization of the financial markets all trigger the expansion of the capital movements between world economies. This increase in the capital flows is the main factor promulgating the globalization of the financial markets in general. Specifically, the globalization of the stock markets has paved up the way to extreme market integration, by which inter-relations among local equity markets incline. Heimonen (2002) argues that since market integration harmonizes economic and fiscal policies, the co-movements between national stock markets further increase. Babecky *et al.* (2013) discuss that integration

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enhances investment opportunities allowing higher returns at the same level of risk. In fact, Agenor (2003) pioneers in studying the benefits and costs of integration; the benefits are the increased financial stability and efficiency of the financial system, along with higher economic growth, while the costs are financial contagion, high volatility in international capital flows and the loss of macroeconomic stability.[3] Bekaert *et al.* (2014) confer that the economies that are highly integrated globally through trade and financial linkages are stroken harder by contagious flows. The costs of financial integration may be pernicious at times of market turmoil due to the contagion spawned by the herding behavior of the investors.[4]

The findings of previous literature on cross-market linkages are mixed, varying with both the study period and equity markets under investigation. However, quite a number of studies emphasize the fact that the crises in the last few decades, particularly, the crash of October 1987, the Asian crisis of 1997, and the 2008 subprime crisis, intensify the integration of national stock markets globally (Arshanapalli and Doukas, 1993; Yang *et al*., 2003; Nam *et al*., 2008; Dooley and Hutchinson, 2009; Assidenou, 2011; Arouri *et al.*, 2012).

In light of the above discussions, we aim to provide a comprehensive research on cross-market linkages for about a 20 year period between 1994 and 2014 with an emphasis on the 2007-2009 credit-crunch crisis. In this end, we investigate the relation between the US equity market and the world's largest stock markets including those of the G20 countries along with some selected European equity exchanges. G20 countries are namely Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States and the European Union, and they form an international forum represented by their finance ministers and central bank governors.[5] G20 has been originally established in 1999 as a group of some developed and developing economies, which altogether account for 84% of gross world product (GWP), 79% of world trade and 65% of the world population.[6] The US is the economy with the highest gross domestic product (GDP) in USD as a single country within the group, closely following the European Union. Furthermore, the US has a pioneering role in world politics and economics, hence the impact of the US financial market on the global markets cannot be contravened. This allusion to the leading position of the US economy has recently been reflected in the 2007-2009 US subprime mortgage crisis.[7] The crisis has originated in the US financial markets but it has almost spontaneously spread all through the world as a contamination. "Great Recession" has started to be used to label the Global Financial Crisis (GFC) as an allegory of the "Great Depression", which was flamed up by the collapse of the Lehman Brothers.

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[3] *For a detailed discussion on the benefit-cost mechanisms of integration see Babecky et al. (2013) and Agenor and Aizenman (2011). Zhou et al. (2013) document that the increase in short-term capital flows raises the volatility in the Chinese stock market.*

4 Pritsker (2001) identifies four different shock and volatility transmission channels; the correlated information channel (King and Wadhwani, 1990), the liquidity channel (Claessens et al., 2001), the cross-market hedging channel (Calvo and Mendoza, 2000) and the wealth effect channel (Kyle and Ziong, 2001).

[5] *www.g20.org; www.oecd.org.*

[6] *G20 studies centre.*

[7] *Curto and Marques (2013) detect a leading equity volatility effect on economic growth in the US; the heightened stock market volatility leads a slow-down in economic growth.*

Therefore, in this study we focus on the pioneering role of the US financial market on the equity markets of G20 countries. However as European Union is a political and economic group of the member European countries, we select 11 member countries (the Netherlands, Greece, Austria, Belgium, the Czech Republic, Finland, Norway, Poland, Portugal, Spain and Sweden) apart from Germany, France,Italy and the UK that are originally in the G20 group economies, since they represent an important part of the global economy both in terms of the depth and breadth of their national stock markets and their volume of international trade. We also include Switzerland in our sample as a part of the ancient Europe no matter it is not an EU member. We analyze the time-varying shock and volatility spillover mechanisms between the US stock market represented by the S&P 500 index and each of the aggregate benchmark stock indices of the remaining 31 economies in the sample.

Our main contribution is to provide an empirical evidence on shock and volatility transmissions between the US and a large number of equity markets both from emerging and developed economies at the same time by utilizing a novel multivariate technique. For this end, we employ a multivariate GARCH model; a fully parametric BEKK-GARCH with its generalization in an asymmetric form (hereafter ABEKK). Along with analyzing time-varying variances and covariances, the ABEKK specification accounts for asymmetric cross-market shock and volatility transmission linkages.[8] Examining the co-movements between security returns is of paramount importance in the formation of portfolio allocation and hedging strategies. Moreover, a thorough understanding of volatility transmission between different assets provides tools to policymakers for effective intervention at times of market turbulence in order to sustain the stability of the financial system. Our findings suggest that cross-market volatilities are significantly transmitted in varying magnitudes and signs.

Moreover, as discussed by Ahmad *et al.* (2013) cross market correlations are of great importance in regard to cross-country optimal portfolio allocation. Thus, studying the interdependence and spillovers between different markets is eminent for investors and portfolio managers to explore the co-movements. The correlation coefficients from the asymmetric form of the ABEKK models display an upward trend over time, signaling the inclination of market integration. Chiang *et al.* (2007) argue that since contagion is described as a significant increase in cross-market co-movements, the existence of contagion has to demonstrate significant dynamic increments in correlations. To test for contagion, we construct a dummy regression analysis on both the correlations and variances during three different phases of the sub-prime crisis[9] and uncover significant increases in both the correlations and variances attesting contagion between the US and the G20 economies. Hence, we also contribute to the existing literature by unfolding the extent of the contagious flows in different phases of the crisis. In this regard, our results are also indicative for dynamic portfolio construction and diversification strategies as well as risk management.

The plan of the paper is as follows: Part 2 presents the empirical methodology. Part 3 discusses the nature of the data and the relevant statistics. In Part 4 we depict the results of the empirical models. Finally, Part 5 concludes.

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[8] *In literature, these types of models capturing news and volatility spillovers are widely used for measuring the extent of market integration (Ng, 2000; Tai, 2007; Horvath and Petrovski, 2013).*

[9] *We use an ad hoc specification for the different phases of the GFC following the the reports of Federal Reserve Board of St. Louis (2009) and the Bank for International Settlements (BIS, 2009).*

2. Methodology

This study utilizes the BEKK-GARCH model in its asymmetric extension. In the methodology part, we first present the VAR framework used for the return filtration. In the second section of this part, we describe the BEKK-GARCH model and its asymmetric form. In the last part, we present the linear regressions with dummy variables to quantify the financial contagion effects.

2.1. VAR Filtration

Firstly, the mean equations for the BEKK (1,1) model are filtered out by the VAR (1) specification. The VAR (1) model can be written as follows:

$$Y_t = \Psi + \Gamma Y_{t-1} + Z_t$$
$$\Psi = \begin{bmatrix} \psi_{11} \\ \psi_{22} \end{bmatrix};\ \Gamma = \begin{bmatrix} \varphi_{11} & \varphi_{12} \\ \varphi_{21} & \varphi_{22} \end{bmatrix};\ Z = \begin{bmatrix} z_{1,t} \\ z_{2,t} \end{bmatrix} \tag{1}$$

where: Y_t is a 2x1 vector of stock returns at time t and Γ is a 2x2 parameter matrix. Z_t is a 2x1 vector of random errors $Z_t = [z_{1t}\ z_{2t}] \sim N(0, H_t)$,where: H_t is a (2x2) vector representing the conditional variance matrix. The diagonal entries in matrix Γ measure the own return effect while the non-diagonal entries represent the return transmission.

2.2. Shock and Volatility Spillovers

This paper investigates the volatility spillovers between the US stocks and the other equity markets by examining the asymmetric responses of volatility spillovers to the unexpected shocks. The BEKK-GARCH model proposed by Engle and Kroner (1995) enables us to quantify the influence of one market on another through spillover effects. The covariance matrices are directly generated from the model and hence the correlations can also be extracted. Specifically, a fully parameterized BEKK-GARCH (1,1) model with n assets yields $(p+q)kn^2+n(n+1)/2$ parameter estimates. Thus, we assume that the lags p=k=q=1 leading to a BEKK-GARCH (1,1) model. The bilateral model for the conditional variance can be mathematically expressed as:

$$H_t = C'C + A' z_{t-1} z'_{t-1} A + B' H_{t-1} B \tag{2}$$

where: H_t, A and B are square matrices and C is an upper triangular matrix. H_t represents a conditional variance-covariance matrix at time t. The diagonal elements in the matrix H_t denote the return variances and the non-diagonal elements are the covariances between the US market and the others. The coefficients in matrix A measure the effects of the unanticipated shocks while the parameters in matrix B present the volatility spillovers.

Even if the GARCH-BEKK model captures both own volatility dependence and cross-volatility effects, it ignores the presence of asymmetries in the risk spillover mechanism. In order to examine the asymmetric effects on the volatility spillovers, we extend the BEKK-GARCH model in an asymmetric form following Kroner and Ng (1998). Compared to the symmetric BEKK-GARCH model, the asymmetrically extended BEKK-GARCH model enables us to distinguish between positive and negative shocks in both own and cross volatility dependence. The asymmetric BEKK-GARCH (ABEKK) model for conditional variance can be written as follows:

$$H_t = C'C + A'z_{t-1}z'_{t-1}A + B'H_{t-1}B + D'\eta_{t-1}\eta'_{t-1}D$$
$$\eta_{t-1} = \begin{bmatrix} \max(0, -z_{1,t-1}) \\ \max(0, -z_{2,t-1}) \end{bmatrix} \tag{3}$$
$$C = \begin{bmatrix} C_{11} & C_{12} \\ 0 & C_{22} \end{bmatrix}, A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}, B = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}, D = \begin{bmatrix} D_{11} & D_{12} \\ D_{21} & D_{22} \end{bmatrix}$$

where: D is a square matrix modeling asymmetry in variances as well as covariances through η_{t-1}. The matrix D captures the asymmetric characteristics of the time-varying variance-covariance, representing covariance asymmetry.[10] The diagonal coefficients of the matrix D quantify the responses of one market to its own shocks, while the off-diagonal parameters measure the response of one market to the shocks of the other market. If any coefficient in D is positive and significant, there is an asymmetric effect. Accordingly, a bad news event will induce a larger volatility of stock markets than a good news event.

2.3. Dummy Variables

We also analyze the changes in the behavior of conditional correlations and conditional volatilities throughout the data period. If a significant change is observed in the time series of the underlying variables, it might indicate contagion effects. We split the entire crisis period into three different phases following the report of Federal Reserve Board of St. Lois (2009) and the Bank for International Settlements (BIS, 2009). These studies distinct the phases throughout the GFC. The first phase (phase 1) is the “initial financial turmoil” (August 1, 2007 – September 15, 2008); the second phase (phase 2) is described as “sharp financial market deterioration” (September 16, 2008 – December 31, 2008); the third phase (phase 3) is a phase of “macroeconomic deterioration” (January 1, 2009 – March 31, 2009).[11] The following regression equations with dummy variables are specified on the changes of the dynamic correlations and volatilities:

$$corr_{ij,t} = \omega + \alpha_1 dummy_{phase1} + \alpha_2 dummy_{phase2} + \alpha_3 dummy_{phase3} + \varepsilon_t \tag{4}$$
$$h_i = c + \beta_1 dummy_{phase1} + \beta_2 dummy_{phase2} + \beta_3 dummy_{phase3} + \varepsilon_t \tag{5}$$

where: $corr_{ij,t}$ is the dynamic correlations between a stock market and S&P 500 and h_i is the conditional volatility of a particular market, which are all derived from the ABEKK models. Any statistically significant and positive dummy coefficient in the conditional correlation or volatility series indicates a considerable increase during the crisis phases. On the contrary, a statistically significant and negative coefficient shows a decline in the series under examination. Therefore, the dummy analysis enables us to analyze contagion at different episodes of the crisis; any significant increase in the co-movement of a stock market with the S&P 500 can be taken as contagion from the US market to the other.

[10] We are grateful to an anonymous reviewer to make this point clearer for us.

[11] The last phase (phase 4) of the crisis is labelled as “stabilization and tentative signs of recovery” (April 1, 2009 onwards). However, as the last phase (phase 4) is a recovery stage, it will not be included in the dummy regression analysis.

3. Data and Descriptive Statistics

We use daily data for the stock markets from late 1994 to early 2014. The summary statistics are presented in Table A1 in the Appendix to save space. The highest mean return is observed for Turkey with 0.121 followed by Brazil (0.075) and both Argentina and Russia (0.064). The most risky stock market measured by its standard deviation is Russia followed by Turkey and Argentina, whereas the market with the lowest standard deviation is Australia. The emerging markets generate higher returns than the developed markets as cited in previous literature (Goetzmann and Jorion, 1999). Out of 32 markets, we find that 24 of them exhibit negative skewness which suggests that negative returns are more probable than positive returns. As can be seen from the kurtosis measures, all the series exhibit excess kurtosis, indicating that the series are not normally distributed and have fat tails which is typical for financial series. The non-normality of the return distributions is also verified from the Jarque-Bera test statistics.

In Table A2 in the Appendix, we document the results from the unit root, autocorrelation and ARCH tests. Our test results confirm that the series under examination are suitable for further GARCH modeling. Furthermore, we substantiate that all the series have autocorrelation by conducting the Box-Pierce test for serial correlation on the raw and the squared returns. Besides, the ARCH tests up to 10 lags confirm that the series have statistically significant ARCH effects. The ADF and the KPSS tests demonstrate that the return data is stationary with no unit roots.

4. Empirical Results

4.1. The ABEKK Model Results

In this section we present the empirical results for the aforementioned asymmetric BEKK-GARCH model performed with quasi-maximum likelihood estimations assuming conditional normality.[12] All of the tables include the associated parameters along with their statistical significance indicated by the p-values. The diagonal shock parameters A_{11} and A_{22} stand for the coefficients of the own shock effects for S&P 500 and the other markets, respectively. The non-diagonal A_{12} and A_{21} show the cross-market shock transmissions between the markets. The diagonal volatility parameters representing the own variances are denoted as B_{11} for S&P 500 and B_{22} for the other equity pair. The non-diagonal B_{12} and B_{21} parameters indicate the cross-market volatility spillover effects.

From Table 1, it is clear that the lagged (past) own news and volatilities significantly impact the current conditional volatility. We find the largest own news coefficient A_{22} (0.345) for the Indonesian stock market. Besides, the current conditional volatility of each market mostly stems from its own past volatility as evidenced from the diagonal variance parameters represented by B_{11} for the S&P 500 and B_{22} for the other equity markets. The largest associated parameter (B_{22}) is found for Finland (0.976). All the diagonal volatility parameters are very close to unity, showing that the current conditional volatilities are strongly connected to the past conditional volatilities. In overall, the diagonal shock and volatility coefficients

[12] *We only document the ABEKK-GARCH model based on the filtered returns. The mean equations are set up in the Vector-Autoregression (VAR) form. For the sake of brevity, we did not display the VAR model results but they are available upon the readers' request.*

suggest that all markets under investigation are significantly impacted by news (shocks) and volatility originating in their own markets.

For international investors and portfolio managers, it is essential to deeply analyze the cross market volatility transmissions in order to make tactical portfolio allocations. Furthermore, cross market spillovers between international stock markets are also highly relevant for international policymakers. On the one hand, they show how much (domestic) markets respond to information generated in foreign markets. On the other hand, they provide information on the speed and dimension of risk propagation across markets. The non-diagonal coefficients in the framework of the ABEKK models enable us to examine the inter-market spillovers.

The ABEKK-GARCH results in Table 1 manifest that there is a significant shock and volatility transmission between the S&P 500 and the other stock markets. The coefficients (A_{12}) representing shock spillovers from the S&P 500 to the other markets are highly significant for 23 of the market pairs. Among the statistically significant parameters, 14 of them are negative, which implies that a shock in the US reduces the volatility of these markets. Our results display that a shock in the S&P 500 increases the volatility in 9 of the markets as suggested by the positive A_{12} parameters. The highest coefficient of cross-market shocks (A_{12}) in absolute terms is reported for S&P 500-Argentina which is followed by S&P 500-Sweden and S&P 500-Brazil pairs which are all negative, indicating a decline in the volatility of these markets following a US equity shock. Furthermore, the Czech Republic, China, Finland, Greece, Italy, Russia, Spain and South Korea seem to be immune to shock spillovers from the US during the study period.

The inter-market shock spillover parameters A_{21} indicate that 14 out of 31 coefficients are statistically insignificant, which denotes that no shock spillover from these markets to the US equities are traced. The largest relevant coefficient (A_{21}) in terms of its magnitude is in the S&P 500-UK equation (-0.201) revealing that the UK is the most efficacious market on the US equities. From the significant parameters, 10 of them are negative implying that the shocks in these markets are transmitted to the US stocks by a reduced effect on the volatility. This may stem from the fact that investors see the US financial markets as a safe haven at times of increased global risk and shift their portfolios towards the US equities when unanticipated shocks in the other markets emerge. For 15 of the market pairs (Argentina, Austria, Australia, Belgium, Brazil, Denmark, Germany, France, India, the Netherlands, Portugal, South Africa, the UK, Sweden, Switzerland) bi-directional shock spillovers are observed, however the news impact of the other markets on the S&P 500 index is to a lesser extent than the other way round. Most importantly the results from the cross-market shock spillovers draw a conclusion that the US stock market has an influential role in the transmission of shocks over most of the markets. We report a higher shock effect over the US stocks only for Belgium, Denmark, the UK, South Korea and Russia.

Table 1

Asymmetric BEKK-GARCH (ABEKK) Model Results

	A_{11}	A_{12}	A_{21}	A_{22}	B_{11}	B_{12}	B_{21}	B_{22}	D_{11}	D_{12}	D_{21}	D_{22}	LL
S.Africa	0.109[a]	0.132[a]	-0.034[b]	0.205[a]	0.947[a]	0.001	0.005	0.937[a]	-0.350[a]	0.053	-0.049[a]	-0.259[a]	-13.353
p-value	0.000	0.000	0.032	0.000	0.000	0.846	0.398	0.000	0.000	0.139	0.004	0.000	
Nether.	0.157[a]	0.123[a]	-0.102[a]	0.077[b]	0.944[a]	-0.008	0.010[c]	0.960[a]	-0.323[a]	0.048	-0.046[b]	-0.336[a]	-12.982
p-value	0.000	0.000	0.000	0.014	0.000	0.291	0.063	0.000	0.000	0.134	0.027	0.000	
S.Arabia	0.038[c]	-0.045[a]	-0.005	0.361[a]	0.928[a]	0.001	0.000	0.928[a]	0.487[a]	0.027[c]	-0.018	0.114[a]	-10.021
p-value	0.062	0.000	0.601	0.000	0.000	0.821	0.949	0.000	0.000	0.073	0.114	0.001	
Argen.	0.076[a]	-0.270[a]	0.010[c]	0.317[a]	0.962[a]	0.029[a]	-0.009[a]	0.908[a]	0.360[a]	0.095[b]	0.005	0.281[a]	-15.015
p-value	0.000	0.000	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.492	0.000	
Greece	0.012	0.002	0.015	0.316[a]	0.957[a]	0.007	-0.008[b]	0.936[a]	0.363[a]	0.058[c]	0.033[a]	0.184[a]	-15.076
p-value	0.477	0.933	0.140	0.000	0.000	0.338	0.020	0.000	0.000	0.064	0.001	0.000	
Australia	0.032	0.116[a]	0.065[b]	0.171[a]	0.951[a]	-0.005	0.023[b]	0.935[a]	0.363[a]	0.087[a]	0.037	-0.258[a]	-11.854
p-value	0.318	0.000	0.015	0.000	0.000	0.211	0.043	0.000	0.000	0.000	0.176	0.000	
Austria	0.006	-0.090[a]	-0.042[b]	-0.179[a]	0.954[a]	0.007	0.000	0.941[a]	-0.374[a]	0.046[c]	-0.011	-0.295[a]	-13.299
p-value	0.890	0.000	0.040	0.000	0.000	0.152	0.940	0.000	0.000	0.067	0.491	0.000	
Belgium	0.108[a]	-0.083[a]	-0.108[a]	-0.139[a]	0.956[a]	0.002	-0.012[b]	0.934[a]	0.342[a]	0.066[a]	0.065[a]	0.329[a]	-12.655
p-value	0.000	0.000	0.000	0.000	0.000	0.767	0.079	0.000	0.000	0.001	0.002	0.000	
Brazil	0.027	-0.218[a]	0.008[c]	0.243[a]	0.960[a]	0.009	-0.004[a]	0.945[a]	-0.369[a]	-0.071[b]	-0.007	-0.276[a]	-14.945
p-value	0.177	0.000	0.079	0.000	0.000	0.179	0.005	0.000	0.000	0.045	0.180	0.000	
Canada	0.029	-0.086[a]	0.020	0.223[a]	0.949[a]	-0.016[b]	0.006	0.973[a]	-0.372[a]	-0.166[a]	-0.013	-0.133[a]	-11.513
p-value	0.294	0.000	0.449	0.000	0.000	0.018	0.455	0.000	0.000	0.000	0.597	0.000	
China	0.050[b]	-0.001	0.006	0.248[a]	0.955[a]	-0.005	-0.004[a]	0.962[a]	0.388[a]	0.061[a]	-0.035[b]	-0.156[a]	-15.000
p-value	0.011	0.902	0.331	0.000	0.000	0.144	0.003	0.000	0.000	0.001	0.034	0.000	
Czechia	0.026	-0.022	0.010	0.314[a]	0.957[a]	0.016[a]	-0.003	0.931[a]	0.361[a]	0.030	0.019	0.155[a]	-13.643
p-value	0.184	0.393	0.456	0.000	0.000	0.007	0.618	0.000	0.000	0.315	0.231	0.000	
Germany	0.091[a]	-0.158[a]	-0.035[c]	0.154[a]	0.961[a]	0.009	-0.008	0.954[a]	-0.322[a]	-0.068[b]	-0.057[a]	-0.291[a]	-13.350
p-value	0.000	0.000	0.091	0.000	0.000	0.162	0.117	0.000	0.000	0.011	0.001	0.000	
Denmark	0.078[a]	-0.077[a]	-0.126[a]	-0.191[a]	0.953[a]	0.003	-0.004	0.936[a]	-0.356[a]	-0.015	-0.037	-0.258[a]	-11.930
p-value	0.001	0.000	0.000	0.000	0.000	0.670	0.655	0.000	0.000	0.622	0.229	0.000	
Finland	0.070[a]	-0.001	-0.008	0.193[a]	0.948[a]	-0.014[b]	0.002	0.976[a]	0.363[a]	0.127[a]	0.032[a]	0.114[a]	-14.578
p-value	0.000	0.941	0.477	0.000	0.000	0.025	0.387	0.000	0.000	0.000	0.001	0.000	
France	0.146[a]	0.120[a]	-0.073[a]	0.076[a]	0.952[a]	0.000	0.003	0.962[a]	-0.309[a]	0.083[a]	-0.050[a]	-0.321[a]	-13.359

	A_{11}	A_{12}	A_{21}	A_{22}	B_{11}	B_{12}	B_{21}	B_{22}	D_{11}	D_{12}	D_{21}	D_{22}	LL
p-value	0.000	0.000	0.000	0.009	0.000	1.000	0.460	0.000	0.000	0.007	0.008	0.000	
UK	0.127[a]	-0.101[a]	-0.201[a]	-0.018	0.954[a]	0.006	0.001	0.958[a]	0.314[a]	0.020	0.029	0.301[a]	-12.140
p-value	0.000	0.000	0.000	0.483	0.000	0.429	0.823	0.000	0.000	0.373	0.351	0.000	
India	-0.041	0.217[a]	0.045[a]	0.247[a]	0.952[a]	-0.002	0.003	0.895[a]	-0.369[a]	-0.325[a]	-0.018	0.361[a]	-14.822
p-value	0.133	0.000	0.000	0.000	0.000	0.790	0.505	0.000	0.000	0.000	0.152	0.000	
Indone.	0.067[a]	0.198[a]	0.001	0.345[a]	0.954[a]	0.005	0.011[b]	0.884[a]	0.366[a]	0.056	0.000	-0.294[a]	-14.261
p-value	0.002	0.000	0.919	0.000	0.000	0.582	0.039	0.000	0.000	0.116	0.977	0.000	
Italy	0.033	0.003	0.024	0.228[a]	0.961[a]	0.009	-0.003	0.947[a]	-0.329[a]	0.041	-0.035[b]	-0.291[a]	-11.719
p-value	0.276	0.925	0.165	0.000	0.000	0.317	0.483	0.000	0.000	0.275	0.034	0.000	
Japan	0.062[a]	0.137[a]	0.017	0.222[a]	0.952[a]	0.008	0.006	0.926[a]	0.379[a]	0.067[a]	-0.013	-0.256[a]	-13.532
p-value	0.003	0.000	0.238	0.000	0.000	0.148	0.302	0.000	0.000	0.006	0.317	0.000	
S.Korea	0.033	-0.007	0.042[a]	0.273[a]	0.952[a]	-0.012[b]	-0.009[a]	0.958[a]	-0.399[a]	-0.179[a]	0.010	0.109[c]	-14.709
p-value	0.180	0.785	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.000	0.606	0.086	
Mexico	0.040[a]	-0.133[a]	0.007	0.212[a]	0.958[a]	-0.003	-0.002	0.960[a]	-0.368[a]	-0.070[a]	-0.009	-0.272[a]	-13.351
p-value	0.044	0.000	0.279	0.000	0.000	0.538	0.416	0.000	0.000	0.003	0.359	0.000	
Norway	0.109[a]	0.095[a]	0.001	0.235[a]	0.952[a]	-0.003	-0.006	0.928[a]	0.338[a]	-0.029	0.048[b]	0.275[a]	-12.788
p-value	0.000	0.000	0.954	0.000	0.000	0.621	0.216	0.000	0.000	0.373	0.013	0.000	
Poland	0.056[b]	-0.175[a]	-0.002	0.230[a]	0.957[a]	0.011[b]	-0.002	0.964[a]	0.359[a]	0.088[a]	0.022[a]	0.087[a]	-15.067
p-value	0.020	0.000	0.843	0.000	0.000	0.030	0.332	0.000	0.000	0.000	0.008	0.003	
Portugal	0.009	0.102[a]	0.067[a]	0.283[a]	0.961[a]	0.022[a]	-0.013	0.908[a]	0.349[a]	-0.033	0.047[b]	0.273[a]	-12.769
p-value	0.786	0.000	0.001	0.000	0.000	0.002	0.153	0.000	0.000	0.220	0.047	0.000	
Russia	0.036[b]	-0.001	-0.023[a]	0.311[a]	0.951[a]	0.021[b]	0.007[a]	0.939[a]	-0.376[a]	0.018	0.000	-0.173[a]	-14.053
p-value	0.049	0.961	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.637	0.966	0.000	
Spain	0.083[a]	0.022	-0.015	0.214[a]	0.957[a]	0.015[b]	-0.002	0.942[a]	-0.321[a]	0.059	-0.052[a]	-0.298[a]	-13.711
p-value	0.008	0.591	0.414	0.000	0.000	0.043	0.630	0.000	0.000	0.121	0.002	0.000	
Sweden	-0.014	-0.235[a]	0.104[a]	0.143[a]	0.957[a]	0.016[c]	-0.012[b]	0.946[a]	0.366[a]	0.007	0.014	0.326[a]	-13.675
p-value	0.654	0.000	0.000	0.000	0.000	0.077	0.035	0.000	0.000	0.862	0.299	0.000	
Switzer.	0.045[c]	-0.160[a]	-0.080[a]	0.126[a]	0.966[a]	0.013[b]	-0.019[b]	0.931[a]	-0.309[a]	-0.005	-0.096[a]	-0.367[a]	-12.078
p-value	0.074	0.000	0.003	0.000	0.000	0.019	0.021	0.000	0.000	0.817	0.000	0.000	
Turkey	0.021	-0.077[a]	0.004	0.279[a]	0.954[a]	-0.018[a]	-0.006[a]	0.952[a]	0.380[a]	0.209[a]	0.019[a]	0.132[a]	-16.632
p-value	0.223	0.003	0.228	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.003	0.000	

a, b and c denote significance at 1%. 5% and 10% respectively.

The parameters of inter-market volatility transmission B_{12} stand for the spillovers from the S&P 500 to the other markets. We document that volatility stemming from the S&P 500 transmits to Argentina, Canada, the Czech Republic, Finland, South Korea, Poland, Portugal, Russia, Spain, Sweden, Switzerland and Turkey, as is evident from the statistically significant coefficients. Among the statistically significant B_{12} parameters, the numbers are negative for Canada, Finland, South Korea and Turkey, expressing that an increase in the lagged volatility of the S&P 500 imposes a decreasing impact on the current conditional volatilities of these equity markets. The other stock exchanges seem to be immune to the volatility shocks stemming from the US stock market. The equity market subject to the highest volatility transmission from the US is Argentina (0.029), followed by Portugal (0.022) and Russia (0.021). On the other hand, a rise in the volatility in the other stock markets affects the volatility of the S&P 500 as well; 13 markets (Argentina, Australia, Belgium, Brazil, China, Greece, Indonesia,the Netherlands, Russia, South Korea, Sweden, Switzerland, Turkey) are found to transmit their volatilities to the US. Most of these countries display a negative volatility transmission parameter (Argentina, Brazil, Belgium, China, South Korea, Sweden, Switzerland, Turkey) which indicates that the lagged volatilities of these equity markets have a declining effect on the current volatility of the US stock market. This result may concede that international investors switch their portfolios towards the US stocks when uncertainty increases in the other markets. That positions the US equity market as a safer investment hub. The overall cross-market volatility results manifest that the volatility transmission from the S&P 500 index to the other markets is stronger in general than the opposite case supporting Cardona *et al.* (2017) who examine the transmission mechanism between the stock returns in the US and Latin American countries and posit significant spillovers from the US to the others. Furthermore, our empirical findings evince significant bidirectional volatility links between S&P 500-Argentina, S&P 500-South Korea, S&P 500-Russia, S&P 500-Sweden, S&P 500-Switzerland and S&P 500-Turkey.

It is a well-known fact that information transmission mechanism can be in an asymmetric form, for this reason, our aim is also to analyze the asymmetric news impact on the market pairs under investigation. The diagonal news impact coefficients D_{11} and D_{22} show that the asymmetry terms for the S&P 500 and the other markets are highly significant at the 1% significance level. The D_{22} coefficients signify that own past negative shocks seem to have a higher impact on the volatilities of 14 stock markets. The D_{11} parameters for the S&P 500 are varying across the models. We investigate the cross-market (off-diagonal) asymmetry terms as one of our main objectives in this study and the results evidence that the bad news from the US is spilled over to Saudi Arabia, Argentina, Greece, Australia, Austria, Belgium, China, Finland, France, Japan, Poland and Turkey. The off-diagonal parameter D_{21} denotes bad news from Belgium, Finland, Greece, Norway, Poland, Portugal and Turkey affect the volatility of the US market. Our findings reveal that Belgium, Greece, Finland, Poland and Turkey are found to have bidirectional asymmetric news transmission with the US equity market. To sum up, our empirical results pronounce the leading and the dominating role of the US economy over the other equity markets. Obstfeld and Rogoff (2009) state that “the interaction among the Fed’s monetary stance, global real interest rates, credit market distortions, and financial innovation created the toxic mix of conditions making the US the epicenter of the global financial crisis”. Amidst the discussions that the US financial markets pioneer the recent crisis, our findings support the previous literature in detecting the domination of the US economy over the others, in particular with its negative news.

In Table 2, the residual diagnostic test results are presented. We apply the Box-Pierce serial correlation test on the squared residuals and ARCH-Lagrange Multiplier test for the remaining heteroskedasticity. The Box-Pierce test statistics reveal that most of the market pairs exhibit no autocorrelation at the 1% and 5% significance levels with the exceptions of S&P500-Brazil and S&P-Italy pairs. More importantly, the remaining heteroskedasticity in the residuals is examined with the ARCH tests after fitting the ABEKK-GARCH models. The statistics indicate that there are no significant remaining ARCH effects at 1% and 5% significance levels with the only exception of S&P500-Italy, for which the ARCH test at lag 40 results 1.378 with a p-value of 0.057. Hence, the residual tests employed justify the use of fully-parametric ABEKK-GARCH type models.

Table 2

Residual Test Results

	Q2(20)	p-value	ARCH(20)	p-value
S.Africa	14.224	0.819	0.706	0.824
Netherlands	30.470[c]	0.063	1.499[c]	0.071
S.Arabia	26.533	0.149	1.252	0.201
Argentina	27.694	0.117	1.427[c]	0.098
Greece	28.442[c]	0.099	1.377	0.122
Australia	5.415	0.999	0.003	1.000
Austria	11.971	0.917	0.614	0.906
Belgium	8.633	0.987	0.426	0.988
Brazil	31.834[b]	0.045	1.554[c]	0.055
Canada	14.080	0.826	0.743	0.784
China	4.893	1.000	0.237	1.000
Czech Rep.	17.714	0.606	0.879	0.615
Germany	26.172	0.160	1.255	0.199
Denmark	12.965	0.879	0.669	0.860
Finland	10.991	0.946	0.556	0.943
France	16.458	0.688	0.833	0.675
UK	23.528	0.264	1.199	0.244
India	5.515	0.999	0.263	1.000
Indonesia	22.864	0.296	1.103	0.338
Italy	39.841[a]	0.005	2.191[a]	0.002
Japan	22.803	0.299	1.152	0.287
S.Korea	20.196	0.446	0.993	0.467
Mexico	24.515	0.221	1.234	0.214
Norway	14.012	0.830	0.681	0.849
Poland	24.138	0.236	1.188	0.254
Portugal	11.845	0.921	0.616	0.905
Russia	13.355	0.862	0.648	0.879
Spain	22.602	0.309	1.149	0.290
Sweden	13.893	0.836	0.674	0.856
Switzerland	18.832	0.533	0.937	0.538
Turkey	13.476	0.856	0.662	0.867

a, b and c denote significance at 1%. 5% and 10% respectively

4.2. Dummy Regression Analysis

This section presents the results from the dummy regression analyses conducted on both the conditional volatilities and correlations.[13] This further investigation enables us to detect the presence of any significant change in the time behavior of variances and co-movements. The statistical significance of the estimated dummy parameters shows the changes in the underlying series during different stages of the GFC as explained in section 2.3. A significant dummy coefficient also implies that the behavior of the volatilities and/or the correlations during the crisis period is significantly different from that of both pre and post crisis periods. As the GFC is originated from the US financial markets, any significant dummy parameter may imply volatility spillover and contagion effects from the crisis epicenter.[14]

In Table 3, the dummy coefficients of the variance OLS equations are depicted. We find that most of the dummy coefficients are positive and statistically significant. The exceptions are observed in the first phase of the GFC "initial financial turmoil" (August 1, 2007 – September 15, 2008), as the flow of the crisis from the US to the other markets may have lags. Indeed, most of these exceptions (Argentina, Brazil, Greece, Italy, South Korea, Russia, Turkey, Mexico, Finland and Poland) are the emerging markets. The results reveal that the market variances greatly increase during the second phase of the GFC "sharp financial market deterioration" (September 16, 2008 – December 31, 2008) compared to the first phase, which signals the intensification of the contagious flows from the US to the other markets. This finding is in line with those of Dimitriou *et al.* (2013) and Dooley and Hutchison (2009) who document that the emerging markets decoupled from the US at the early stages of the GFC and recoupled in the second and the third phases. During the third phase the dummy coefficients are lower compared to the second phase indicating that the rise in the stock market volatilities in this phase slows down.

Table 3

Dummy Regressions for Variance Equations

	ω	β_1	p value	β_2	p value	β_3	p value
S&P500	1.179	0.347^a	0.000	2.390^a	0.000	1.109^a	0.000
S.Africa	1.179	0.346^a	0.000	2.389^a	0.000	0.053^a	0.001
Netherlands	1.160	0.193^a	0.000	2.586^a	0.000	1.275^a	0.000
S.Arabia	1.349	0.835^a	0.000	3.236^a	0.000	1.506^a	0.000
Argentina	1.883	-0.134^a	0.000	2.508^a	0.000	0.850^a	0.000
Greece	1.661	-0.055^a	0.000	1.813^a	0.000	0.868^a	0.000
Australia	0.725	0.327^a	0.000	1.447^a	0.000	0.720^a	0.000
Austria	1.135	0.425^a	0.000	3.148^a	0.000	1.828^a	0.000
Belgium	1.022	0.380^a	0.000	2.528^a	0.000	0.906^a	0.000
Brazil	1.959	0.057	0.322	2.593^a	0.000	0.637^a	0.000
Canada	0.988	0.263^a	0.000	3.009^a	0.000	1.564^a	0.000

[13] *The dynamic correlations extracted from the ABEKK-GARCH models provide evidence that the correlations are time-varying and that they are mostly positive. Moreover, the correlations display an upward trend for most of the markets, which shows that the markets under investigation become more integrated with the US overtime. To conserve space, the time-varying conditional correlation graphs are not included in the text, but they are available upon the request of the interested reader.*

[14] *By many scholars, the US stock market is accepted as the source of the GFC. In their studies, similar to ours, they mainly use dummy regressions to capture the contagion effect from the US to the other markets (see among others Syllignakis and Kouretas,2011; Dimitrou,2013; Kenourgios and Dimitriou, 2015; Demiralay and Ulusoy, 2016; Mensi et al., 2016).*

	ω	β_1	p value	β_2	p value	β_3	p value
China	1.663	0.947[a]	0.000	1.360[a]	0.000	0.528[a]	0.000
Czech Rep.	1.192	0.209[a]	0.000	3.136[a]	0.000	1.138[a]	0.000
Germany	1.292	0.112[a]	0.002	2.130[a]	0.000	1.288[a]	0.000
Denmark	0.916	0.276[a]	0.000	2.116[a]	0.000	0.938[a]	0.000
Finland	1.600	-0.002	0.964	1.539[a]	0.000	0.941[a]	0.000
France	1.244	0.181[a]	0.000	2.049[a]	0.000	1.084[a]	0.000
UK	0.954	0.353[a]	0.000	2.243[a]	0.000	1.206[a]	0.000
India	1.481	0.522[a]	0.000	2.686[a]	0.000	1.120[a]	0.000
Indonesia	1.393	0.410[a]	0.000	2.132[a]	0.000	0.519[a]	0.000
Italy	1.380	-0.092[b]	0.017	1.890[a]	0.000	1.226[a]	0.000
Japan	1.143	0.302[a]	0.000	2.224[a]	0.000	0.628[a]	0.000
S.Korea	1.598	-0.079	0.113	2.044[a]	0.000	0.694[a]	0.000
Mexico	1.398	0.062	0.104	1.807[a]	0.000	0.784[a]	0.000
Norway	1.119	0.333[a]	0.000	3.188[a]	0.000	1.459[a]	0.000
Poland	1.603	0.003	0.925	1.654[a]	0.000	1.355[a]	0.000
Portugal	1.016	0.270[a]	0.000	2.061[a]	0.000	0.676[a]	0.000
Russia	2.323	-0.405[a]	0.000	4.949[a]	0.000	1.931[a]	0.000
Spain	1.312	0.157[a]	0.000	1.954[a]	0.000	0.958[a]	0.000
Sweden	1.295	0.320[a]	0.000	2.374[a]	0.000	1.398[a]	0.000
Switzerland	0.921	0.248[a]	0.000	1.828[a]	0.000	0.865[a]	0.000
Turkey	2.420	-0.309[a]	0.000	1.369[a]	0.000	0.100	0.472

Note: a and b denote significance at 1% and 5%, respectively.

In Table 4, the dummy variable analysis results for the conditional correlations are reported. Our findings substantiate that the dynamic correlations are significantly higher during the crisis episodes compared to the tranquil periods. However, the impact of the crisis noticeably differs across both the markets and the crisis stages. In the first phase we find that some markets decouple from the US; Norway, China and Japan are the only equity markets that are found to display lower co-movements with the S&P 500 index, while we tabulate an insignificant dummy coefficient for Saudi Arabia. However, in the second and the third phases all the markets examined display recoupling with the US and their interdependence with the US inclines, suggesting that contagion deepens when there is a sharp financial market/macroeconomic deterioration.

Table 4

Dummy Regressions for Correlation Equations

	ω	α_1	p value	α_2	p value	α_3	p value
S&P500 - S.Africa	0.329	0.037[a]	0.000	0.154[a]	0.000	0.971[a]	0.000
S&P500 - Netherlands	0.544	0.066[a]	0.000	0.158[a]	0.000	0.152[a]	0.000
S&P500 - S.Arabia	0.137	0.006	0.471	0.051[a]	0.001	0.133[a]	0.000
S&P500 - Argentina	0.477	0.066[a]	0.000	0.272[a]	0.000	0.287[a]	0.000
S&P500 - Greece	0.201	0.109[a]	0.000	0.286[a]	0.000	0.246[a]	0.000
S&P500 - Australia	0.177	0.025[a]	0.000	0.066[a]	0.000	0.056[a]	0.000
S&P500 - Austria	0.361	0.091[a]	0.000	0.211[a]	0.000	0.194[a]	0.000
S&P500 - Belgium	0.483	0.091[a]	0.000	0.140[a]	0.000	0.055[a]	0.001
S&P500 - Brazil	0.558	0.118[a]	0.000	0.261[a]	0.000	0.222[a]	0.000
S&P500 - Canada	0.693	0.048[a]	0.000	0.137[a]	0.000	0.120[a]	0.000
S&P500 - China	0.015	-0.050[a]	0.000	0.011[a]	0.192	0.035[a]	0.000
S&P500 - Czech Rep.	0.254	0.091[a]	0.000	0.193[a]	0.000	0.240[a]	0.000
S&P500 - Germany	0.541	0.066[a]	0.000	0.203[a]	0.000	0.187[a]	0.000

	ω	α_1	p value	α_2	p value	α_3	p value
S&P500 - Denmark	0.366	0.121[a]	0.000	0.171[a]	0.000	0.141[a]	0.000
S&P500 - Finland	0.427	0.082[a]	0.000	0.274[a]	0.000	0.183[a]	0.000
S&P500 - France	0.561	0.057[a]	0.000	0.092[a]	0.000	0.119[a]	0.000
S&P500 - UK	0.527	0.091[a]	0.000	0.140[a]	0.000	0.174[a]	0.000
S&P500 - India	0.144	0.056[a]	0.000	0.064[a]	0.000	0.011	0.532
S&P500 - Indonesia	0.124	0.014[a]	0.006	0.028[a]	0.004	0.089[a]	0.000
S&P500 - Italy	0.543	0.053[a]	0.000	0.107[a]	0.000	0.151[a]	0.000
S&P500 - Japan	0.179	-0.018[a]	0.000	0.049[a]	0.000	0.149[a]	0.000
S&P500 - S.Korea	0.180	0.056[a]	0.000	0.175[a]	0.000	0.098[a]	0.000
S&P500 - Mexico	0.592	0.174[a]	0.000	0.239[a]	0.000	0.248[a]	0.000
S&P500 - Norway	0.400	-0.019[a]	0.007	0.161[a]	0.000	0.118[a]	0.000
S&P500 - Poland	0.287	0.117[a]	0.000	0.244[a]	0.000	0.158[a]	0.000
S&P500 - Portugal	0.347	0.081[a]	0.000	0.157[a]	0.000	0.157[a]	0.000
S&P500 - Russia	0.297	0.017[b]	0.017	0.024[a]	0.087	0.044[a]	0.006
S&P500 - Spain	0.493	0.043[a]	0.000	0.144[a]	0.000	0.217[a]	0.000
S&P500 - Sweden	0.488	0.064[a]	0.000	0.105[a]	0.000	0.132[a]	0.000
S&P500 - Switzerland	0.474	0.105[a]	0.000	0.233[a]	0.000	0.182[a]	0.000
S&P500 - Turkey	0.180	0.153[a]	0.000	0.397[a]	0.000	0.322[a]	0.000

Note: a and b denote significance at 1% and 5%, respectively.

Our results are in line with Chiang *et al.*'s (2007) discussion on the Asian crisis which asserts that contagion spreads from the earlier-hit economies to the others and as public awareness grows the correlations between stock returns and volatilites surmount as a consequence of the contagious herd behavior.[15] Although we find mixed results for the dummy coefficients in terms of their magnitudes, from the figures it is apparent that emerging markets display a higher degree of co-movement at different phases of the crisis. This finding also supports the results of Li and Giles (2015) who analyze the spillover effects between developed stock markets and Asian emerging stock markets and document significant spillovers, particularly during the crisis periods. However, our results also suggest the heterogeneity of the emerging markets as they do not share common socio-economic and financial characteristics; more industrialized developing countries such as Russia and China exhibit a much lower interdependence with the US while Turkey, South Africa, Argentina, Brazil and Greece show a higher degree of co-movement with the S&P 500 during the GFC.[16] Noticeably, Turkish equity market seems to be the most affected displaying the highest dummy coefficients for all the phases of the GFC. This may stem from the fact that international investors control about 60% of the Turkish stock market and among the international portfolio investments more than 30% are owned by the US investors.[17] Hence, some emerging markets still possess diversification benefits for international investors as

[15] *Similar arguments are asserted both by Dimitriou et al. (2013) and Dooley and Hutchison (2009) on the GFC.*

[16] *Russia is found to be segmented from international markets in some studies; Popa et al. (2015) find out that Russia displays a low level of integration with the US between 2004 and 2014, while Chelley-Steeley (2005) concludes that the Russian equity market remains heavily segmented from the developed markets. Furthermore, Aloui et al. (2011) discuss that the emerging markets that are commodity-price dependent (Brazil and Russia) are more reliant on the US than the finished-product export-oriented markets (China and India) which is partially in line with our findings.*

[17] *Annual reports of MKK in 2014 and 2015, for further details see www.mkk.org.tr.*

indicated by the dummy analyses, but the evident increase in the correlations during the different phases of the crisis entails that the gains from international diversification diminish in stressed financial markets.

5. Conclusion

This paper analyzes the dynamic nature of the volatility transmission mechanisms between the US stock market and those of the G20 countries. We expand the data set by including twelve other EU member countries to provide a more comprehensive research and empirical evidence on the volatility transmission dynamics of the markets under investigation. The findings from this paper suggest that shock and volatility spillovers significantly subsist from the US to the other G20 markets while we also observe that the transmission mechanism runs from some of the other markets to the US as well. The bilateral shock transmission is more common than the bilateral volatility transmission. We substantiate the dominant role of the US in transmitting shocks, however in case of the volatilities; the spillovers from the other markets to the US are more common. Moreover, asymmetric news coefficients provide evidence of an emphasized effect of the negative shocks from the US on the volatility of the other markets. Our results also depict the asymmetric response of the S&P 500 index to the news from the other markets; however the sign of the reaction is mixed across the markets.

Furthermore, we examine whether the market variances and conditional correlations significantly change during the different stages of the GFC. By utilizing OLS regressions constructed with dummy variables, we report significant increases in both the correlations and the variances. Our findings suggest that the correlations between the US and the other markets significantly increase during the second and the third phases of the GFC. Additionally, the second phase of the crisis witnesses significant inclination in market variances signaling the contagious flow of the turmoil from the US to the other markets. Bekaert *et al.* (2014) also report the contagious flow from the US to the global equity markets during the credit-crunch crisis and ponder that countries with weak economic fundamentals, high fiscal and current account deficits are more prone to the contagion from the US. Alike, our OLS regressions with dummy analysis underlie that almost all of the equity markets under investigation are significantly affected by the contagion from the US, but the impact on the emerging markets is greater. Nonetheless, more industrialized emerging markets such as Russia and China demonstrate a lower level of interdependence with the US, whereas economies with high fiscal and current account deficits such as Turkey, South Africa, Argentina, Brazil and Greece are more severely influenced. This result points out the heterogeneity of the emerging markets as a group, implying that some emerging markets may offer better diversification opportunities to international investors than the others. In this regard, our results suggest indicative implications for international investors and portfolio managers to ensure higher returns and lower risk since analyzing the mechanisms of shock and volatility transmissions can provide significant advantages in risk diversification and cross-market hedging.

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Appendix

Table A1

Summary Statistics

	Mean	Median	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Jarque-Bera (p)
S&P500	0.031	0.069	1.235	-0.233	10.950	12770.940[a]	0.000
Netherlands	0.015	0.059	1.440	-0.139	9.023	7568.951[a]	0.000
Argentina	0.064	0.126	2.078	0.028	9.670	9112.600[a]	0.000
Greece	0.003	0.016	1.791	-0.018	6.692	2834.273[a]	0.000
Australia	0.020	0.040	0.980	-0.477	9.049	7809.919[a]	0.000
Austria	0.016	0.060	1.392	-0.378	10.496	11714.880[a]	0.000
Belgium	0.015	0.044	1.225	0.006	9.064	7656.443[a]	0.000
Brazil	0.075	0.114	2.300	0.458	14.506	27427.130[a]	0.000
Canada	0.027	0.077	1.189	-0.659	12.268	18244.100[a]	0.000
China	0.021	0.037	2.026	1.262	27.014	117869.700[a]	0.000
Czech Rep.	-0.001	0.024	1.413	-0.423	14.137	25432.980[a]	0.000
Germany	0.031	0.102	1.508	-0.126	7.365	3982.092[a]	0.000
Denmark	0.038	0.083	1.096	-0.433	8.995	6968.933[a]	0.000
Finland	0.027	0.071	1.836	-0.255	8.814	7091.491[a]	0.000
France	0.015	0.043	1.458	-0.012	7.478	4176.204[a]	0.000
UK	0.014	0.051	1.182	-0.160	8.965	7403.110[a]	0.000
India	0.034	0.068	1.603	-0.181	9.382	8473.159[a]	0.000
Indonesia	0.045	0.084	1.608	-0.185	10.802	12451.65[a]	0.000
Italy	-0.004	0.059	1.570	-0.080	7.047	2806.976[a]	0.000
Tokyo	-0.007	0.004	1.354	-0.272	8.727	6784.084[a]	0.000
Mexico	0.057	0.076	1.553	0.062	9.356	8415.185[a]	0.000
Norway	0.036	0.109	1.389	-0.627	9.219	7596.66[a]	0.000
Poland	0.017	0.026	1.820	-0.211	5.828	1675.984[a]	0.000
Portugal	0.012	0.029	1.164	-0.340	11.008	13455.300[a]	0.000
Russia	0.064	0.123	2.832	0.112	16.792	32298.440[a]	0.000
S.Africa	0.048	0.089	1.382	-0.404	9.180	7552.766[a]	0.000
S.Arabia	0.039	0.089	1.326	-1.002	15.746	34648.82[a]	0.000
S.Korea	0.011	0.055	1.789	-0.269	7.244	3811.963[a]	0.000
Spain	0.021	0.080	1.480	-0.009	7.877	4953.849[a]	0.000
Sweden	0.031	0.071	1.523	0.074	6.628	2744.303[a]	0.000
Switzerland	0.028	0.066	1.120	-0.204	8.782	6985.294[a]	0.000
Turkey	0.121	0.135	2.599	0.030	8.040	5277.806[a]	0.000

Note: a denotes significance at 1% level.

Table A2

The Results of the Tests for Further Modeling

	ARCH (10)	ARCH (10) - p	Q (10)	Q (10) - p	Q2 (10)	Q2 (10) - p	ADF	KPSS
S&P500	159.0257[a]	0.000	57.887[a]	0.000	3625.100[a]	0.000	-53.600	0.171
Netherlands	167.7249[a]	0.000	70.893[a]	0.000	4017.800[a]	0.000	-33.992	0.124
Argentina	91.61678[a]	0.000	50.398[a]	0.000	696.490[a]	0.000	-64.582	0.058
Greece	61.94888[a]	0.000	74.811[a]	0.000	1335.600[a]	0.000	-63.013	0.098
Australia	124.5008[a]	0.000	11.411[a]	0.000	3074.600[a]	0.000	-72.570	0.047
Austria	176.6234[a]	0.000	28.344[a]	0.002	4706.900[a]	0.000	-65.915	0.120
Belgium	127.9244[a]	0.000	75.872[a]	0.000	3268.100[a]	0.000	-42.406	0.091
Brazil	59.86915[a]	0.000	84.548[a]	0.000	1262.200[a]	0.000	-67.601	0.088
Canada	161.5966[a]	0.000	37.483[a]	0.000	3778.700[a]	0.000	-53.097	0.048
China	106.6343[a]	0.000	43.140[a]	0.000	1597.100[a]	0.000	-69.412	0.043
Czech Rep.	183.1183[a]	0.000	73.544[a]	0.000	3974.800[a]	0.000	-62.920	0.229
Germany	107.4933[a]	0.000	25.146[a]	0.005	2585.000[a]	0.000	-71.185	0.095
Denmark	141.9856[a]	0.000	40.311[a]	0.000	3296.600[a]	0.000	-63.207	0.108
Finland	46.6018[a]	0.000	27.353[a]	0.002	927.420[a]	0.000	-68.913	0.081
France	100.7686[a]	0.000	47.946[a]	0.000	2363.300[a]	0.000	-72.589	0.085
UK	145.5119[a]	0.000	86.565[a]	0.000	3554.000[a]	0.000	-32.083	0.079
India	47.71792[a]	0.000	60.774[a]	0.000	861.690[a]	0.000	-65.308	0.127
Indonesia	53.27518[a]	0.000	144.230[a]	0.000	1112.600[a]	0.000	-59.716	0.065
Italy	88.55817[a]	0.000	41.371[a]	0.000	1979.300[a]	0.000	-63.993	0.087
Tokyo	140.2502[a]	0.000	26.672[a]	0.003	3244.800[a]	0.000	-68.395	0.064
Mexico	61.3578[a]	0.000	56.748[a]	0.000	1152.800[a]	0.000	-64.442	0.045
Norway	170.7086[a]	0.000	21.924[b]	0.015	4487.400[a]	0.000	-65.969	0.077
Poland	83.91286[a]	0.000	66.997[a]	0.000	2112.500[a]	0.000	-63.171	0.036
Portugal	66.82634[a]	0.000	77.291[a]	0.000	1387.500[a]	0.000	-63.937	0.112
Russia	70.98669[a]	0.000	50.177[a]	0.000	1291.100[a]	0.000	-58.662	0.060
S.Africa	82.09819[a]	0.000	46.609[a]	0.000	1635.200[a]	0.000	-64.856	0.037
S.Arabia	139.685[a]	0.000	81.025[a]	0.000	3494.400[a]	0.000	-65.417	0.136
S.Korea	86.15133[a]	0.000	55.174[a]	0.000	1956.200[a]	0.000	-65.608	0.071
Spain	81.75073[a]	0.000	41.188[a]	0.000	1863.700[a]	0.000	-51.918	0.067
Sweden	79.84723[a]	0.000	29.703[a]	0.001	1800.600[a]	0.000	-71.117	0.103
Switzerland	152.4322[a]	0.000	59.577[a]	0.000	3866.700[a]	0.000	-33.198	0.106
Turkey	73.76933[a]	0.000	34.591[a]	0.000	1310.600[a]	0.000	-68.964	0.041

Note: a and b denote significance at 1% and 5%, respectively.