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Intra- and inter-regional return and volatility spillovers across emerging and developed markets: Evidence from stock indices and stock index futures

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ABSTRACT

We provide empirical evidence on the patterns of intra- and inter-regional transmission of information across 10 developed and 11 emerging markets in Asia, the Americas, Europe and Africa using both stock indices and stock index futures. The main transmission channels are examined in the period from 2005 to 2014 through the analysis of return and volatility spillovers around the most recent crises based on the generalized vector autoregressive framework. Our findings demonstrate that markets are more susceptible to domestic and region-specific volatility shocks than to inter-regional contagion. A novel result reported in our study is a difference in patterns of international signals transmission between models employing indices and futures data. We conclude that futures data provide more efficient channels of information transmission because the magnitude of return and volatility spillovers across futures is larger than across indices. Our findings are relevant to practitioners, such as stock market investors, as well as policy makers and can help enhance their understanding of financial markets interconnectedness.

1. Introduction

The international information transmission mechanisms across markets, through both returns and volatility, have theoretical significance and a wide range of practical implications. The phenomenon of volatility spillovers occurs when volatility in one market triggers volatility in other markets. This effect can be particularly visible during periods of turmoil which diminishes the benefits of international portfolio diversification for investors. It is further amplified by the recent technological advances, which have increased the accessibility of foreign information for domestic investors and speeded up information flows. The investigation of return and volatility spillovers between stock markets within various geographical regions is an important topic, which contributes to our knowledge about global financial interconnectedness.

There are various fields of literature to which the analysis of return and volatility spillovers is related, for example, the literature on financial contagion, hedging, asset allocation, and stock market efficiency. Ideas of transmission of volatility across markets underpinned the "heat waves" and "meteor showers" hypotheses postulated by Engle, Ito, and Lin (1990) and have natural implications in the analysis of predictability of stock market returns (see, e.g., Ibrahim & Brzeszczynski, 2009, 2014, among others). Indeed, while return and volatility spillovers can limit the benefits of global diversification, the knowledge about international information transmission mechanisms can provide the opportunity to predict the behavior of a domestic market by using foreign information. Therefore, the estimation of directional return and volatility spillovers is important in understanding the channels of intra- and inter-regional information transmission, which can be used to create successful trading strategies.

Although the return and volatility spillovers across stock market indices have been actively studied over the last two decades, this topic is even more relevant now due to its practical significance and the nature of volatility itself which varies over time. However, the existing empirical evidence about intra- and inter-regional return and volatility spillovers around financial crises mainly focuses on the information transmission across the largest developed stock markets. For example, the markets in Japan, the UK, and the USA were considered in the early literature by Engle et al. (1990), King and Wadhwani (1990), Becker, Finnerty and Gupta (1990), Hamao, Masulis and Ng (1990), or more recently by Ibrahim and Brzeszczynski (2009, 2014), to name but a few. On the other hand, globalization and the development of new technologies have caused an increase in the integration of emerging markets with the world economy. This effect has many practical implications. For example, the increasing economic integration of emerging and developed stock markets has become a crucial issue for portfolio managers because volatility spillovers tend to diminish the opportunities for international diversification in emerging economies. Moreover, the global financial crisis (GFC), together with the European debt crisis (EDC), has resulted in a new wave of academic literature on contagion and stock market integration in the periods before, during and after these episodes. Therefore, we

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contribute to this knowledge by providing the analysis of cross-border return and volatility spillovers around the most recent crisis episodes, which includes both developed and emerging markets.

The purpose of this paper is to analyze the return and volatility spillovers across 21 emerging and developed markets in order to explore the new geography of financial information transmission mechanisms across countries around the recent crisis episodes. The markets selected for our sample represent the broad regions of Asia, the Americas, Europe, and Africa. Therefore, the primary contribution of our research to the literature is the investigation of volatility spillovers in the sample which is not restricted only to developed markets (see, e.g., Beirne & Fratzscher, 2013; Beirne et al, 2013; Cho, Hyde & Nguyen, 2014; Diebold & Yilmaz, 2009, 2012; Singh, Kumar & Pandey, 2010; Syriopoulos, 2007; Worthington & Higgs, 2004).

Another important contribution of our study is the use of futures data. The question of which data is appropriate to use in analyses of international information transmission and global market linkages is still a matter of debate between academics and supervisory bodies. Gagnon and Karolyi (2006) provide a comprehensive summary of academic literature on global market linkages. They reveal that analysis of stock indices is the primary focus of spillover studies. Various studies apply different data frequencies, such as weekly, daily (close-to-close, open-to-close, or close-to-open returns), or higher frequency intra-day data. However, all these papers used stock indices data to investigate international information transmission. Our findings presented in this study suggest that employing stock indices data only limits understanding of the practical implications of empirical results because the trading strategy based on investing in various stock indices is an approximation that only makes sense in a theoretical context. In reality, stock indices cannot be traded by investors as financial instruments. Investors with diversification goals can only buy constituent stocks (which is costly but also time-consuming) and such trades are not possible to execute in a single transaction, which on the other hand can be done using stock index futures (Subrahmanyam, 1991). Employing stock index futures data in analysis of international information transmission is more realistic from the point of view of the construction, testing, and execution of actual trading strategies and, therefore, the results of such empirical research are more useful for practitioners. Hence, in this paper, we go beyond the investigation of return and volatility spillovers across stock markets using only the data for indices, and we employ both stock indices and stock index futures data to compare the differences between them. Although existing literature employed futures data in the analysis of spillovers and addressed several important issues in finance, the evidence about global return and volatility transmission across futures markets is still very limited.[1] Therefore, our findings provide a novel contribution to the existing literature.

Futures can offer several obvious advantages for investors, such as lower costs of trading or high trading volume (i.e., high liquidity). Therefore, from the perspective of international information transmission mechanisms, futures markets can provide more efficient channels of transmission of information flows. The findings of this paper are also particularly relevant to a broad range of practitioners, such as active portfolio managers, various institutional investors, and liquidity traders. Furthermore, Antoniou, Holmes, and Priestley (1998) argue that the volatility of futures increases the volatility of the underlying spot markets, which has prompted the public to blame futures trading for the intensity of the financial distress witnessed during the crisis episodes; hence, the difference in observed patterns of information transmission between models employing index and futures data provided in our study is also relevant to policy makers and financial regulators.

In summary, this paper contributes to existing knowledge in three important areas. First, we provide empirical evidence from both stock indices and stock index futures data about differences in information transmission mechanisms. Our analysis contributes to the emerging literature, which employs alternative data to simple stock indices in the analysis of international information transmission effects. Our findings suggest that employing futures data makes the results more practically applicable in the construction of trading strategies based on transmission of foreign information. Second, the methodology of Diebold and Yilmaz (2009, 2012) is utilized to explore the new geography of financial linkages through an analysis of both intra- and inter-regional return and volatility spillovers across 21 developed and emerging markets from four regions: Asia, the Americas, Europe, and Africa. Third, we provide evidence about the changing intensity of return and volatility spillovers around the most recent crisis episodes with respect to structural breaks in the volatility of both futures and spot markets returns, which contributes to the contagion literature. The conclusions from our study are also important for policy makers and financial regulators because they provide a global perspective on spillovers across financial markets from 2005 to 2014. This is crucial to an enhanced understanding of the new requirements for financial regulation.

The remainder of the paper is organized as follows: Section 2 outlines the methodology, Section 3 describes the data, Section 4 presents the empirical results, and Section 5 offers conclusions and outlines potential directions for further research.

2. Methodology

In this study, we apply the Diebold and Yilmaz (2009) methodological framework, which provides separate measures of return and volatility spillovers based on forecast error variance decompositions from a vector autoregressive (VAR) model. However, due to the fact that it relies on the Cholesky factor identification of VAR, the results may be dependent on variable order. Subsequently, Diebold and Yilmaz (2012) replaced the Cholesky factorization on KPPS (Koop, Pesaran, & Potter, 1996; Pesaran & Shin, 1998) variance decomposition, allowing the above methodological limitation to be avoided but retaining all the advantages of their general framework. In this paper, therefore, we estimate return and volatility spillovers using a generalized vector autoregressive following the Diebold and Yilmaz method (2012).

A covariance stationary of N-variable VAR (p) can be described as follows:

$$X_t = \sum_{i=1}^{p} \psi_i X_{t-i} + \varepsilon_t, \quad (1)$$

where X_t is a vector of returns or vector of volatilities of either spot or futures markets in our sample, ψ_i is a parameter matrix and $\varepsilon \sim (0, \Omega)$ is a vector disturbance.

The moving average representation of the VAR is given by

$$X_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \quad (2)$$

$$Q_i = \psi_1 A_{i-1} + \psi_2 A_{i-2} + \ldots \psi_p A_{i-p}, \quad (3)$$

where A_0 being an $N \times N$ identity matrix and with $A_i = 0$ for $i < 0$.

N-variable VAR variance decomposition, introduced by Sims (1980), allows for each variable X_i to be added to the shares of its H-step-ahead error forecasting variance coming from shocks of variable X_j (where $\forall i \neq j$ for each observation). The record of these cross-variance shares, under investigation in this paper, provides information of spillovers from one market to another. Additionally, the Diebold and Yilmaz (2012) framework allows for the examination of how variable

[1] The first group of studies focuses on commodity futures, rather than financial futures, contributing to the literature on hedging (see, for example, Lau & Bilgin, 2013). The second major group of studies considers the relationship between spot and related futures markets (Gannon, 2005; Harris, 1989). However, these papers do not provide a cross-country perspective on return and volatility transmission. Only a few papers consider futures-spot relationships in the context of global financial markets interdependencies (Antoniou, Pescetto, & Violaris, 2003; Kao, Ho, & Fung, 2015). In addition, evidence in the majority of papers is still restricted to developed countries, which again exemplifies the contribution of this research.

X_i depends on its own shocks, and for a calculation of total volatility spillover.

As has been mentioned above, the employed framework relies on KPPS H-step-ahead forecast error, which is invariant to the ordering, and can be defined for $H = [1, 2 \dots +\infty)$, as

$$\vartheta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \Omega e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_h \Omega A_h' e_i\right)} \tag{4}$$

where Ω is the variance matrix for the error vector ε, σ_{jj} is the standard deviation of the error term for the jth equation and e_i is the selection vector with one as the ith element and zero otherwise. $\sum_{j=1}^{N} \vartheta(H) \neq 1$. This means that the sum of the elements in each row of the variance decomposition is not equal to 1. The normalization of each entry of the variance decomposition matrix by the row sum made as

$$\tilde{\vartheta}_{ij}^{g}(H) = \frac{\vartheta_{ij}^{g}(H)}{\sum_{j=1}^{N} \vartheta_{ij}^{g}(H)} \tag{5}$$

where $\sum_{j=1}^{N} \tilde{\vartheta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{N} \tilde{\vartheta}_{ij}^{g}(H) = N$.

The total volatility contributions from KPPS variance decomposition are used to calculate the total spillover index:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^{N} \tilde{\vartheta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\vartheta}_{ij}^{g}(H)} \times 100 = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^{N} \tilde{\vartheta}_{ij}^{g}(H)}{N} \times 100 \tag{6}$$

Similarly, directional spillover indices are calculated to measure spillovers from market i to all markets j and reverse direction of transmission from all markets j to market i, using Eqs. (7) and (8), respectively,

$$S_{.i}^{g}(H) = \frac{\sum_{\substack{j=1 \\ i\neq j}}^{N} \tilde{\vartheta}_{ji}^{g}(H)}{\sum_{i,j=1N} \tilde{\vartheta}_{ij}^{g}(H)} \times 100 \tag{7}$$

$$S_{i.}^{g}(H) = \frac{\sum_{\substack{j=1 \\ i\neq j}} N\, \tilde{\vartheta}_{ij}^{g}(H)}{\sum_{i,j=1N} \tilde{\vartheta}_{ij}^{g}(H)} \times 100 \tag{8}$$

The difference between total shocks transmitted to market i and those transmitted from market i to all markets is defined as *net volatility spillover* (Eqs. (7) and (8)). In a similar way, *net pairwise spillovers* are calculated for each K pairs of markets in the sample:

$$\begin{aligned} S_{ij}^{g}(H) &= \frac{\tilde{\vartheta}_{ji}^{g}(H)}{\sum_{i,k=1}^{N} \tilde{\vartheta}_{ik}^{g}(H)} - \frac{\tilde{\vartheta}_{ij}^{g}(H)}{\sum_{j,k=1}^{N} \tilde{\vartheta}_{jk}^{g}(H)} \times 100 \\ &= \frac{\tilde{\vartheta}_{ji}^{g}(H) - \tilde{\vartheta}_{ij}^{g}(H)}{N} \times 100 \end{aligned} \tag{9}$$

The total spillover index is applied to investigate the global and regional trends of spillover activity around the crisis episodes, while directional spillovers are used to demonstrate how much each market contributes to all the other markets, providing information about the channels of intra- and inter-regional information transmission across the selected markets.

3. Data

Twenty-one stock markets were selected for empirical investigation of return and volatility transmission. The data sample contains 10 developed and 11 emerging markets from four geographical regions: Europe (United Kingdom, Germany, France, Spain, Switzerland, Russia, Hungary, and Turkey), Africa (South Africa), Asia (Hong Kong, Japan, Singapore, South Korea, China, India, Taiwan, and Malaysia), and the Americas (Canada, USA, Mexico, and Brazil). We used market value weighted indices, which were denominated in local currency. The opening, closing, and high and low prices of market indices were obtained on a daily basis from the Bloomberg database for the period October 3, 2005, to October 3, 2014. Open-to-close returns for working days were calculated using 2350 observations (see Table 1 for descriptive statistics).

In a similar way, the daily opening, closing, high and low prices of stock market index futures were obtained from the Bloomberg database for the period October 4, 2010,[2] to October 3, 2014, providing 1045 observations of daily futures returns. Several futures contracts were available for each stock market during the year with various maturity dates. The tickers of futures contracts employ abbreviations for both the contract and its expiration date. The first two letters represent the contract, the third letter represents the contract expiration month,[3] and a fourth figure represents the expiration year. For example, the futures contract with DAX 30 as underlying index and delivery date of December 14, 2014, has a ticker GXZ4, where GX represents the contract, *Z* represents December, and number 4 represents the year. For this research, prices of futures contracts with the closest expiration dates were obtained due to higher trading volume on these securities. All returns were calculated as a difference of natural logarithm of closing price and natural logarithm of opening price. The stock market returns on nonsynchronous holidays were assumed to be zero. Zero returns on nonsynchronous holidays reflect actual returns on nontrading days.

The basic statistics for the stock markets returns and volatility for the whole estimation period are presented in Table 1, while Table 2 provides a comparison of descriptive statistics for futures and spot market returns for a subsample from October 4, 2010, to October 3, 2014. Both Tables 1 and 2 show that the means for futures and spot markets are close to zero. The analysis of skewness indicates that there are both positively and negatively skewed time series in the sample. The analysis of kurtosis demonstrates the high value of kurtosis of stock indices data (i.e., there are sharp peaks in stock indices returns) for the whole estimation period and significantly lower kurtosis for the subsample period. There is a high frequency of extreme values of returns for both spot markets and futures markets. The Jarque–Bera statistics reject null hypotheses for all markets; therefore all series are not normally distributed. The Lagrange multiplier test of Engle (1982) was employed to test series on autoregressive conditional heteroskedasticity. The test indicated the existence of the ARCH effect for the majority of time series.

The Ljung–Box test statistics at lag 10, Q (10), provide evidence of autocorrelation for the series. The Augmented Dickey-Fuller (ADF) and the Phillips-Perron (P-P) stationarity tests indicate that all series in the sample are stationary.[4] Analysis of volatility is sensitive to the measure of volatility that is used. The advantages of range estimators over classical estimators of volatility are widely discussed in literature (Garman & Klass, 1980; Parkinson, 1980; Rogers & Satchell, 1991, Yang & Zhang, 2000).[5] The Rogers and Satchell (1991) volatility estimator has been used because it is more efficient than classical volatility

[2] The time period for futures data analysis starts on 4th of October 2010 due to the data availability for futures markets of some emerging countries in the sample.

[3] Expiration Month Symbol Codes are January – F; February – G; March – H; April – J; May – K; June – M; July – N; August – Q; September – U; October – V; November – X; December - Z.

[4] Tables with results are available upon request.

[5] The range estimators use information on daily trading range- the difference between the high and low prices for a particular security over certain time interval, while classic volatility estimators use close-to-close prices.

Table 1
Descriptive statistics for stock indices returns and volatility.

Series		Stock market returns: Mean	Variance	Skewness	Kurtosis	JB	LB(10)	ARCH	Stock market volatility: Mean	Variance	Skewness	Kurtosis	JB	LB (10)	ARCH
Hong Kong	HKG	−0.000473	0.000125	0.3549	16.1201	25493.5808	91.8201	157.314	−0.004169	0.014328	−0.2953	11.4524	12876.7242	76.7253	158.943
Japan	JPN	−0.000285	0.000140	−0.6787	16.1214	25628.9362	35.5222	286.389	−0.000017	0.013336	0.4698	12.5664	15548.8086	57.1156	263.393
Singapore	SGP	−0.000160	0.000109	0.1811	8.6447	7330.3267	29.9749	104.949	−0.000788	0.004269	−0.7551	11.8934	14073.9622	41.7884	89.899
China	CHN	0.001117	0.000272	−0.3677	3.1777	1041.7141	23.5777	43.425	−0.016895	0.021389	0.1314	2.8325	792.3373	53.1365	78.276
South Korea	KOR	−0.000389	0.000118	−0.3125	10.3114	10449.2169	38.2961	142.246	−0.004912	0.003536	−0.2968	7.2053	5117.9790	74.3752	54.251
Malaysia	MYS	0.000167	0.000038	−0.5187	7.0534	4976.7826	28.4938	74.252	−0.004807	0.002139	−0.2043	5.5741	3058.6343	17.0638	57.714
Taiwan	TWN	−0.001110	0.000091	−0.0688	4.3586	1862.0193	27.8881	48.660	0.002982	0.007780	0.1241	3.1831	998.1450	28.9523	50.153
India	IND	0.000018	0.000236	0.0387	10.2232	10234.1755	28.7833	34.797	−0.005076	0.015594	−0.3091	7.6859	5821.6206	24.9198	21.783
UK	GBR	0.000077	0.000154	−0.1336	8.3565	6844.5464	51.0849	132.823	−0.003983	0.012026	−0.1506	6.0276	3566.4275	32.2127	131.945
Germany	GER	0.000013	0.000151	0.2411	8.6713	7385.1895	13.6901	57.011	−0.007436	0.012960	−0.1500	5.3372	2798.0486	10.8235	101.548
France	FRA	−0.000384	0.000146	−0.3336	4.2120	1780.7115	23.1389	72.710	−0.004402	0.012595	−0.0050	3.6399	1297.2925	12.5694	141.437
Spain	ESP	−0.000248	0.000191	0.0603	6.8150	4549.1029	9.9383	48.751	−0.010406	0.019325	−0.1077	5.1290	2580.4548	12.3494	76.582
Switzerland	SUI	−0.000190	0.000085	−0.3328	6.6981	4436.4252	19.0082	113.169	−0.002732	0.008090	−0.0797	6.0383	3572.5844	22.4355	225.418
Russia	RUS	0.000008	0.000469	−0.4720	12.6419	15736.0824	62.0699	67.104	−0.001812	0.024423	0.5053	9.3821	8718.9497	30.6038	56.755
Hungary	HUN	−0.000771	0.000210	−0.4969	4.6701	2232.2476	35.5889	69.073	−0.001663	0.024514	0.2677	3.3378	1118.9833	44.6279	91.415
South Africa	ZAF	0.000450	0.000165	−0.1893	3.9028	1505.4868	28.2537	107.821	−0.007941	0.017911	0.1867	2.9955	892.2639	14.3253	138.439
Turkey	TUR	−0.000214	0.000283	−0.1678	2.0887	438.2098	18.8890	24.340	−0.009095	0.039454	0.0201	1.3433	176.8326	29.5182	34.978
Canada	CAN	−0.000198	0.000108	−0.7688	10.5876	11207.7173	28.1940	169.851	−0.004786	0.007291	0.2693	8.6032	7275.7335	85.0714	232.810
USA	USA	0.000230	0.000156	−0.3998	10.8674	11626.6857	56.7757	136.674	−0.006451	0.008971	0.1681	10.0198	9841.4621	127.4640	184.810
Mexico	MEX	0.000396	0.000174	0.1175	6.3094	3903.2948	28.7805	69.029	−0.008273	0.020044	−0.0338	4.3533	1856.0491	17.3314	92.139
Brazil	BRA	0.000201	0.000310	−0.0313	6.8414	4583.3511	13.6928	138.046	−0.007521	0.039030	−0.1184	4.0234	1590.5435	40.1095	185.261

Note: The statistic is significant at the 1% level. JB is the Jarque–Bera test for the null hypothesis of normality. LB (10) is the Ljung–Box test of the null hypothesis that the first 10 autocorrelations are zero. ARCH is the Lagrange multiplier test proposed by Engle (1982).

estimators and it is drift independent, which is confirmed by Shu and Zhang (2006)[6]:

$$\delta^2_{RS} = h_t(h_t - c_t) + l_t \times (l_t - c_t) \quad (10)$$

where h_t is the normalized high price, l_t is the normalized low price and c_t is the normalized closing price.

Daily volatilities were calculated for futures and spot markets using Eq. (10), where all prices are transformed to a natural logarithm. According to ADF and P-P tests, all volatility series of both futures and stock indices time-series are stationary. Descriptive statistics for volatility of stock indices are presented in Table 1.

Table 3 summarizes the descriptive statistics for volatility of futures and stock indices for the subsample (October 4, 2010–October 3, 2014) for comparison purposes.

4. Empirical evidence

4.1. Full-sample period analysis

The empirical results are presented in the form of spillover tables. Table 4 reports "input–output" decomposition of spillovers indices for stock markets returns, and Table 5 deals with volatility. In contrast to Diebold and Yilmaz (2009) who report that return and volatility spillovers are of the same magnitude, we found that the total spillover index for returns (71%) is higher than the estimated total spillover index for volatility (56%)[7]; therefore, the magnitude of returns spillovers is higher than volatility spillovers. These differences in magnitude in return and volatility spillovers are evident in all 21 markets in the sample, but especially so for the emerging market of Taiwan, where the results in the row, *Contribution to Others*, are 40.89% for return and only 1.0% for volatility. Similar significant differences are evident in Korea and India. The row *Contribution to Others* demonstrates which stock market is the most influential in the data sample. While Rapach, Strauss, and Zhou (2013), among others, argued that USA tends to be the most influential market, in our sample, the UK stock market had the highest value of spillovers (126%), with the American market only second highest (116.28%). Among emerging markets, the highest return spillover was detected from Mexico (101.14%), Brazil (102.30%), and South Africa (82.76%). The lowest value of the return spillover index (contribution to others) in the whole sample had China (18.88%) and Japan (35.34%). Table 5 presents the results for volatility. For the majority of markets, volatility spillovers are less intense than return spillovers (the values of spillover indices are lower for volatility). The lowest magnitude of volatility spillovers is detected in the channel from the emerging market of Taiwan to other markets, with 96.90% contribution from its own market innovations and just 1.0% contribution to other markets indicated. In contrast, the highest magnitude of volatility spillovers is found across developed European countries, such as the UK, Germany, France, Spain, and Switzerland.

The column *From Others* shows which market is the most sensitive to external shocks. Tables 4 and 5 demonstrate the reverse direction of spillovers (from all foreign markets to a domestic market), which can be assessed by considering the entries of rows for each particular market (horizontal entries). For both the UK and the USA, the value of return spillovers from others markets is very high (84.48% and 81.30%, respectively). The lowest value of spillovers from other markets has the stock markets of China, with returns of 37.61%, and Taiwan, with a volatility of 6.06%. Analysis of both *Contribution to Others* and *From Others* together with other entries in Tables 4 and 5 provides an accurate

[6] The underlying assumption of range estimators is that a security price follows a geometric Brownian motion, deviation from which will affect the accuracy of estimators. The Rogers and Satchell range estimator allows a nonzero drift in the continuous return path and its accuracy is independent from the size of the drift. See Shu and Zhang (2006) for more details.

[7] This means that 76% and 56% of forecast error variance comes from spillovers.

Table 2
Descriptive statistics for futures and spot market *returns* for subsample: October 4, 2010–October 3, 2014.

Series	Futures markets returns							Stock indices returns						
	Mean	Variance	Skewness	Kurtosis	JB	LB(10)	ARCH	Mean	Variance	Skewness	Kurtosis	JB	LB(10)	ARCH
HKG	−0.000046	0.000080	0.0618	1.1555	58.7980	13.0745	2.394	−0.000597	0.000057	0.0893	1.2806	72.7962	13.4438	4.470
JPN	0.000480	0.000169	−0.6556	4.7114	1041.3870	16.3805	24.154	−0.000137	0.000090	−1.6491	15.8084	11354.9854	29.7982	11.236
SGP	0.000159	0.000072	−0.3024	1.5678	122.9537	15.3452	38.006	−0.000279	0.000038	−0.0836	3.0606	409.0767	26.3899	21.507
CHN	−0.000392	0.000127	0.2648	2.9110	381.1743	14.5219	1.642	0.000505	0.000138	0.1319	2.3689	247.3805	26.8470	1.905
KOR	−0.000098	0.000126	−0.2911	3.3975	517.3607	20.2770	34.838	−0.000594	0.000067	−0.3397	3.0478	424.5633	23.6268	43.478
MYS	0.000108	0.000029	−0.1166	3.5493	550.8823	26.6260	26.161	0.000079	0.000020	−0.3898	2.6076	322.5316	14.3407	13.824
TWN	−0.000033	0.000053	−0.0360	2.9264	373.1069	4.3247	12.797	−0.000943	0.000050	−0.2162	2.8661	365.8240	10.4127	20.603
IND	0.000195	0.000127	0.0025	0.8236	29.5362	12.5795	6.187	−0.000592	0.000086	−0.1962	1.1581	65.0979	15.6000	13.007
GBR	0.000128	0.000071	0.0764	5.9787	1557.4057	23.6851	52.247	0.000148	0.000087	−0.2520	2.7385	337.6012	12.0960	35.966
GER	0.000171	0.000115	−0.1284	4.6299	936.2159	11.9011	27.224	−0.000007	0.000114	−0.3051	5.1555	1173.5130	10.4761	35.716
FRA	0.000063	0.000127	−0.1227	3.3390	488.0746	15.9620	30.758	−0.000073	0.000123	−0.3401	4.3407	840.5354	10.8930	39.755
ESP	−0.000436	0.000189	−0.2483	3.2270	464.1624	10.0237	27.263	−0.000265	0.000191	−0.2302	3.3782	506.1530	10.8516	27.563
SUI	0.000205	0.000060	−0.0197	5.3376	1240.5632	34.1648	34.911	0.000154	0.000056	−0.6668	9.3181	3858.0322	21.6241	87.975
RUS	−0.000112	0.000307	−0.4624	3.3102	514.3454	10.9898	6.978	−0.000270	0.000253	−0.5510	4.3799	888.1439	15.8750	8.435
HUN	−0.000332	0.000142	−0.3061	4.0806	741.3342	17.4160	20.915	−0.000669	0.000134	−0.5972	4.2767	858.4762	16.3510	9.816
ZAF	0.000200	0.000068	−0.0667	2.1089	194.4341	20.5406	7.585	0.000486	0.000076	−0.2583	1.5491	116.1137	14.6892	18.665
TUR	−0.000210	0.000261	−0.4160	3.0563	436.8775	13.5127	17.782	−0.000821	0.000213	−0.2444	1.1792	70.9443	8.9423	20.704
CAN	0.000090	0.000057	0.1112	3.7144	602.8902	22.7195	10.046	0.000076	0.000043	−0.2450	2.0801	198.8620	36.0817	22.583
USA	0.000624	0.000085	−0.3459	4.6806	974.7690	38.3841	67.243	0.000466	0.000084	−0.6238	6.7990	2080.5688	60.5330	102.785
MEX	0.000124	0.000071	0.0035	2.0844	189.1801	20.7434	25.722	0.000244	0.000084	−0.3603	3.7416	632.1834	24.4081	29.446
BRA	−0.000545	0.000151	−0.0063	1.1523	57.8224	14.9228	27.267	−0.000249	0.000177	−0.2250	2.1131	203.2376	5.9161	20.161

Note: The ARCH effect is significant at the 5% level except China. JB is the Jarque–Bera test for the null hypothesis of normality. LB (10) is the Ljung–Box test of the null hypothesis that the first 10 autocorrelations are zero. ARCH is the Lagrange multiplier test proposed by Engle (1982). The mnemonics are defined as in Table 1.

Table 3
Descriptive statistics for futures and spot markets *volatility* for subsample: October 4, 2010–October 3, 2014.

Series	Futures markets volatility							Stock indices volatility						
	Mean	Variance	Skewness	Kurtosis	JB	LB(10)	ARCH	Mean	Variance	Skewness	Kurtosis	JB	LB(10)	ARCH
HKG	0.000386	0.009363	−0.0630	1.1979	63.1762	11.8892	5.276	−0.002882	0.006420	−0.1291	0.9360	41.0449	12.0104	9.484
JPN	−0.009450	0.018652	0.0637	4.2834	799.5783	35.3095	63.694	0.001266	0.008710	1.1064	11.6030	6075.1801	36.9934	6.881
SGP	−0.001587	0.002983	−0.137252	2.5815	293.4543	17.1828	20.330	0.000084	0.001521	0.0031	2.5196	276.4165	17.1988	27.128
CHN	0.004447	0.007166	−0.4118	2.1245	226.0521	19.4956	2.801	−0.005264	0.010364	−0.1706	1.7891	144.4446	28.1497	8.987
KOR	−0.001135	0.004377	0.1017	2.2535	222.9112	22.9178	36.944	−0.003888	0.002616	0.0549	3.4046	505.2318	31.2248	22.216
MYS	−0.002242	0.001904	−0.1656	3.6930	598.6087	17.8767	4.720	−0.003903	0.001444	−0.2192	8.0613	2837.9047	20.9649	2.449
TWN	−0.001614	0.004742	−0.0107	2.9641	382.5801	11.0855	22.440	0.002166	0.004752	0.2864	1.9069	172.6182	18.3977	10.077
IND	−0.006421	0.01259	0.0022	0.3416	5.0805	20.2068	10.442	−0.002578	0.009459	−1.7065	24.7313	27138.8026	10.7680	0.268
GBR	−0.007076	0.00453	−0.8378	10.7152	5121.5552	37.9671	23.159	−0.005115	0.007170	−0.0569	5.0409	1106.9674	13.5156	101.164
GER	−0.009241	0.008648	−0.0734	5.2173	1186.1487	26.4371	43.191	−0.007196	0.010681	0.1694	3.6258	577.3993	20.2388	91.028
FRA	−0.007977	0.008569	0.0201	3.5039	534.6449	14.2283	57.731	−0.005083	0.010509	0.1474	3.8727	656.8182	17.0136	118.796
ESP	−0.004155	0.01774	0.2479	3.3201	490.6619	12.9842	63.807	−0.009820	0.019088	0.2172	3.2022	454.7002	10.2892	67.296
SUI	−0.005528	0.004608	0.1859	9.1474	3649.3275	48.1257	96.113	−0.003827	0.005497	0.3274	10.1772	4528.4784	19.1657	239.042
RUS	−0.006912	0.05249	0.1483	2.0545	187.6248	17.3527	16.352	−0.002503	0.014942	0.3330	2.6726	330.3341	11.4051	15.536
HUN	−0.002759	0.012511	0.0304	2.2212	214.9848	16.4618	36.928	−0.002095	0.015453	0.3035	2.0920	206.5998	13.5072	17.991
ZAF	−0.006675	0.00832	0.0362	1.3850	83.7470	21.0209	14.897	−0.009409	0.008869	0.1800	1.1618	64.4161	19.3637	19.844
TUR	−0.001639	0.005904	0.0701	1.1532	58.7585	30.8709	21.024	0.003945	0.033920	0.0013	1.3558	80.0408	24.1537	30.699
CAN	−0.004236	0.002987	−0.1655	3.0748	416.4431	37.5372	31.036	−0.004196	0.002730	−0.1811	3.5407	551.5798	46.2796	43.521
USA	−0.009201	0.005559	0.0871	6.6460	1924.5497	38.9962	81.463	−0.008145	0.004676	0.4654	6.2085	1716.0575	58.5513	102.047
MEX	−0.003315	0.009511	0.0230	1.6909	124.5825	17.4786	34.758	−0.005704	0.010399	0.2726	1.7412	144.9551	16.5366	29.023
BRA	0.003618	0.020939	−0.0896	0.5611	15.1079	16.1826	18.635	0.001355	0.022897	0.0605	0.5441	13.5270	12.1669	23.082

Note: The ARCH effect is significant at the 5% level except India. JB is the Jarque–Bera test for the null hypothesis of normality. LB (10) is the Ljung–Box test of the null hypothesis that the first 10 autocorrelations are zero. ARCH is the Lagrange multiplier test proposed by Engle (1982).The mnemonics are defined as in Table 1.

Table 4
Return spillovers across stock markets.

Region	market	HKG	JPN	SGP	CHN	KOR	MYS	TWN	IND	Sum	GBR	GER	FRA	ESP	SUI	RUS	HUN	TUR	Sum	ZAF	CAN	USA	MEX	BRA	Sum	From others
		Asia									Europe and Africa										Americas					
Asia	HKG	31.92	3.64	11.64	5.18	6.17	3.74	5.54	5.22	73.04	4.40	1.30	0.66	0.50	0.31	3.10	0.39	0.32	10.99	3.63	0.64	3.60	3.68	4.42	12.34	68.08
Asia	JPN	3.94	35.66	4.58	1.04	8.88	1.62	4.33	2.52	62.58	4.90	3.64	2.71	1.77	2.86	2.99	1.56	0.69	21.11	3.74	0.99	4.02	3.77	3.79	12.57	64.34
Asia	SGP	11.20	3.76	28.68	2.16	6.67	5.11	5.40	6.43	69.41	4.87	1.98	1.22	1.19	0.80	3.92	0.55	0.80	15.33	4.22	0.63	2.88	3.59	3.94	11.04	71.32
Asia	CHN	9.99	2.16	4.56	62.39	3.67	3.53	3.62	1.99	91.91	1.07	0.01	0.04	0.04	0.11	1.07	0.06	0.11	2.51	1.48	0.29	0.67	1.29	1.84	4.10	37.61
Asia	KOR	6.92	9.09	7.40	2.14	33.92	3.33	9.32	2.69	74.81	3.66	1.13	0.58	0.38	0.39	3.23	0.49	0.61	10.47	3.73	1.08	3.51	3.00	3.40	10.99	66.08
Asia	MYS	5.21	2.10	7.49	2.46	4.08	42.59	4.80	4.33	73.05	3.63	1.34	1.30	1.01	0.78	3.01	1.21	0.84	13.13	3.40	1.13	2.01	3.62	3.66	10.42	57.41
Asia	TWN	7.22	5.20	7.51	2.33	11.62	4.69	40.68	1.82	81.08	2.87	0.63	0.56	0.36	0.40	2.38	0.18	0.25	7.64	3.15	1.00	2.72	2.01	2.41	8.14	59.32
Asia	IND	5.62	1.95	7.45	1.18	2.68	2.85	1.52	33.39	56.64	5.21	3.29	2.59	2.24	2.12	3.89	1.69	1.98	23.02	5.06	1.83	3.98	4.90	4.57	15.28	66.61
Sub–total		82.00	63.56	79.33	78.87	77.68	67.47	75.22	58.39	582.52	30.61	13.32	9.67	7.50	7.76	23.59	6.15	5.59	104.19	28.41	7.59	23.39	25.87	28.03	84.88	490.77
Europe and Africa	GBR	2.10	1.32	2.61	0.25	1.50	1.22	0.85	2.27	12.12	15.52	9.27	9.00	6.78	7.39	4.67	2.83	2.73	58.18	6.56	2.85	8.26	5.90	6.12	23.14	84.48
Europe and Africa	GER	0.76	0.22	1.16	0.00	0.50	0.28	0.12	1.27	4.31	10.21	17.04	13.62	10.02	9.63	3.54	4.30	3.39	71.74	4.76	2.03	7.22	5.21	4.74	19.20	82.96
Europe and Africa	FRA	0.38	0.02	0.69	0.01	0.14	0.21	0.06	0.87	2.38	9.91	13.54	17.05	11.98	11.25	3.13	4.47	3.63	74.95	4.17	2.53	6.74	4.71	4.52	18.50	82.95
Europe and Africa	ESP	0.37	0.05	0.87	0.02	0.16	0.23	0.05	1.01	2.76	9.14	12.22	14.68	20.77	9.61	2.83	4.48	3.71	77.45	3.62	1.90	6.13	3.97	4.17	16.17	79.23
Europe and Africa	SUI	0.26	0.01	0.50	0.04	0.13	0.17	0.08	0.80	2.01	9.86	11.65	13.63	9.55	20.76	2.33	4.08	3.69	75.55	3.66	2.84	6.94	4.57	4.44	18.79	79.24
Europe and Africa	RUS	2.43	1.67	3.17	0.43	2.10	1.36	1.23	2.77	15.16	7.46	5.77	4.78	3.57	2.95	23.54	3.51	3.29	54.88	7.67	3.16	6.32	6.31	6.49	22.29	76.46
Europe and Africa	HUN	0.43	0.02	0.48	0.02	0.13	0.54	0.05	1.31	2.99	6.10	8.35	8.84	7.17	6.66	4.35	32.82	4.71	79.01	4.09	1.92	4.48	3.68	3.84	13.92	67.18
Europe and Africa	TUR	0.30	0.02	0.95	0.01	0.53	0.36	0.23	1.66	4.06	6.34	7.12	7.67	6.37	6.59	4.79	5.09	35.42	79.37	3.98	1.09	3.90	3.85	3.75	12.59	64.58
Sub–total		7.04	3.34	10.43	0.78	5.18	4.37	2.68	11.97	45.79	74.54	84.97	89.28	76.21	74.82	49.18	61.57	60.55	571.13	38.50	18.32	50.00	38.20	38.07	144.59	617.09
	ZAF	2.35	1.78	3.00	0.45	2.14	1.55	1.36	2.99	15.62	8.88	6.15	5.32	3.74	3.94	6.58	2.52	2.29	39.40	20.27	4.06	6.77	7.00	6.88	24.71	79.73
Americas	CAN	0.50	0.18	0.45	0.07	0.24	0.37	0.23	0.24	2.28	4.66	4.21	5.27	3.26	4.87	0.81	1.60	0.89	25.58	2.12	36.01	15.04	9.63	9.35	70.03	63.99
Americas	USA	1.81	0.60	1.80	0.10	1.26	0.68	0.46	1.47	8.19	8.31	7.68	7.33	5.46	6.17	2.94	2.44	1.98	42.30	3.87	7.97	18.70	9.78	9.19	45.64	81.30
Americas	MEX	2.41	0.73	2.42	0.40	1.62	1.12	0.68	1.83	11.21	7.02	6.28	5.74	3.93	4.57	3.66	2.24	2.20	35.64	4.87	5.59	11.03	20.88	10.78	48.28	79.12
Americas	BRA	2.82	0.82	2.80	0.60	1.91	1.17	0.94	2.16	13.20	7.50	5.73	5.40	4.08	4.38	3.80	2.29	2.04	35.22	5.00	5.33	10.04	10.66	20.54	46.58	79.46
Sub–total		7.54	2.32	7.46	1.17	5.03	3.34	2.31	5.70	34.87	27.49	23.91	23.74	16.72	19.99	11.20	8.57	7.11	138.74	15.85	54.90	54.82	50.95	49.87	210.53	303.87
Contr to others*		67.01	35.34	71.53	18.88	56.12	34.14	40.89	45.66	369.57	126.00	111.30	110.96	83.41	85.76	67.01	45.98	40.13	670.55	82.76	82.76	116.28	101.14	102.30	368.58	1491.45
Contr incl own**		98.93	71.01	100.21	81.27	90.04	76.73	81.57	79.05	678.80	141.52	128.34	128.01	104.18	106.51	90.55	78.81	75.54	853.46	103.03	103.03	134.98	122.02	122.85	464.71	71.0%

Note: From others—directional spillover indices measure spillovers from all markets *j* to market *i*. Contribution to others—directional spillover indices measure spillovers from market *i* to all markets *j*. Contribution including own—directional spillover indices measure spillovers from market *i* to all markets *j*, including contribution from own innovations of market *i*. Other columns contain net pairwise (*i,j*)th spillovers indices. Total return spillover index demonstrates that 71.0% of forecast error variance comes from spillovers. The mnemonics are defined as in Table 1.

Table 5
Volatility spillovers across stock markets.

Region/ market		Asia									Europe and Africa										Americas					From others
		HKG	JPN	SGP	CHN	KOR	MYS	TWN	IND	Sum	GBR	GER	FRA	ESP	SUI	RUS	HUN	TUR	Sum	ZAF	CAN	USA	MEX	BRA	Sum	
Asia	HKG	46.82	4.08	16.37	5.45	0.02	6.14	0.01	0.01	78.89	1.91	0.92	0.99	0.57	0.67	2.80	0.32	0.51	8.69	2.06	1.62	2.85	2.72	3.17	10.36	53.18
	JPN	4.82	61.35	5.48	1.70	0.06	2.81	0.08	0.04	76.34	3.23	2.28	1.82	1.37	1.89	2.98	1.37	0.43	15.37	2.59	1.09	1.48	1.73	1.40	5.70	38.65
	SGP	16.60	4.25	43.89	2.33	0.02	6.23	0.04	0.07	73.43	3.13	1.56	1.61	1.32	1.14	3.81	0.45	0.76	13.78	2.70	2.59	2.82	2.23	2.45	10.09	56.11
	CHN	8.64	2.56	3.73	77.92	0.10	3.37	0.05	0.06	96.43	0.17	0.02	0.06	0.03	0.05	0.38	0.18	0.21	1.11	0.29	0.47	0.31	0.65	0.74	2.16	22.08
	KOR	0.10	0.09	0.06	0.17	93.94	0.22	0.10	3.85	98.53	0.16	0.09	0.16	0.12	0.19	0.08	0.14	0.18	1.12	0.04	0.14	0.06	0.06	0.05	0.31	6.06
	MYS	7.91	2.88	7.88	2.63	0.03	59.96	0.01	0.06	81.37	2.06	0.76	1.03	0.79	0.65	2.81	0.71	0.61	9.43	2.24	1.60	1.44	1.78	2.14	6.96	40.04
	TWN	0.03	0.03	0.30	0.39	0.03	0.02	96.90	0.06	97.76	0.32	0.29	0.18	0.19	0.22	0.17	0.12	0.04	1.53	0.25	0.07	0.09	0.19	0.12	0.46	3.10
	IND	0.01	0.12	0.15	0.03	3.57	0.14	0.06	93.52	97.61	0.26	0.16	0.18	0.10	0.13	0.44	0.16	0.15	1.57	0.26	0.06	0.18	0.11	0.21	0.57	6.48
Sub-total		84.94	75.35	77.85	90.62	97.77	78.88	97.26	97.68	700.36	11.24	6.08	6.03	4.48	4.94	13.48	3.45	2.90	52.60	10.42	7.65	9.24	9.47	10.26	36.63	225.70
Europe and Africa	GBR	0.79	0.39	1.18	0.04	0.01	0.63	0.04	0.09	3.16	18.23	11.84	13.17	10.33	11.39	4.32	3.10	3.20	75.59	6.10	3.81	4.94	3.18	3.22	15.15	81.77
	GER	0.40	0.16	0.63	0.00	0.00	0.25	0.04	0.05	1.54	12.17	18.58	15.92	12.06	11.46	3.26	3.74	3.10	80.28	4.42	3.11	4.64	3.04	2.95	13.75	81.42
	FRA	0.37	0.08	0.58	0.01	0.01	0.24	0.04	0.05	1.36	12.78	15.06	17.65	13.38	11.90	3.35	3.59	3.09	80.81	4.64	3.11	4.38	2.82	2.88	13.19	82.35
	ESP	0.31	0.06	0.60	0.01	0.00	0.23	0.05	0.04	1.30	11.88	13.53	15.85	20.89	10.71	3.17	3.55	3.20	82.78	4.30	2.74	3.91	2.38	2.59	11.62	79.11
	SUI	0.34	0.03	0.47	0.01	0.01	0.20	0.05	0.06	1.17	13.01	12.72	13.97	10.64	20.78	2.59	3.26	3.22	80.19	4.33	3.32	4.80	3.12	3.07	14.31	79.22
	RUS	1.99	1.22	2.74	0.19	0.02	1.36	0.07	0.16	7.75	7.64	6.02	6.17	4.96	4.07	31.56	4.63	4.96	70.00	8.69	3.06	3.30	3.46	3.73	13.56	68.44
	HUN	0.32	0.05	0.39	0.03	0.16	0.40	0.05	0.11	1.52	6.67	7.84	7.94	6.61	6.19	5.40	38.27	4.49	83.40	5.16	2.20	2.88	2.40	2.45	9.92	61.73
	TUR	0.29	0.07	0.63	0.07	0.04	0.43	0.07	0.09	1.68	7.34	6.90	7.38	6.41	6.56	6.50	4.76	40.57	86.43	5.08	1.32	2.02	1.60	1.86	6.81	59.43
Sub-total		4.80	2.06	7.22	0.36	0.24	3.74	0.40	0.65	19.48	89.73	92.50	98.05	85.28	83.06	60.14	64.90	65.82	639.48	42.73	22.68	30.87	22.00	22.76	98.32	593.47
	ZAF	1.28	0.85	1.67	0.11	0.02	1.13	0.05	0.06	5.17	9.63	6.95	7.59	5.93	6.03	7.90	3.86	3.44	51.34	28.66	3.54	3.55	3.89	3.85	14.83	71.34
Americas	CAN	0.93	0.37	1.28	0.11	0.00	0.64	0.07	0.02	3.41	6.09	4.88	5.23	3.90	4.74	1.87	1.22	0.72	28.65	2.49	29.84	15.98	9.38	10.24	65.45	70.16
	USA	1.44	0.28	1.29	0.03	0.01	0.53	0.04	0.02	3.64	6.23	6.13	6.13	4.64	5.67	1.74	1.68	1.07	33.29	2.21	14.26	25.28	10.65	10.65	60.85	74.72
	MEX	1.77	0.25	1.37	0.26	0.02	0.70	0.07	0.01	4.44	4.99	4.91	4.81	3.39	4.52	2.14	1.49	1.21	27.46	2.83	9.66	12.87	30.12	12.61	65.26	69.88
	BRA	2.05	0.21	1.58	0.32	0.01	0.72	0.00	0.06	4.95	4.98	4.64	4.83	3.66	4.40	2.12	1.57	1.16	27.36	2.60	10.46	12.43	12.32	29.88	65.09	70.12
Sub-total		6.18	1.10	5.52	0.72	0.03	2.59	0.19	0.11	16.45	22.29	20.56	20.99	15.59	19.34	7.88	5.96	4.16	116.77	10.13	64.23	66.56	62.48	63.39	256.65	284.88
Contr to others*		50.38	18.02	48.37	13.88	4.13	26.38	1.00	4.98	167.15	114.66	107.51	115.00	90.39	92.59	57.85	39.90	35.76	653.65	63.28	68.26	84.94	67.72	70.39	291.31	1175.38
Contr incl own**		97.20	79.37	92.26	91.80	98.07	86.34	97.90	98.50	741.45	132.89	126.09	132.65	111.28	113.37	89.40	78.17	76.33	860.18	91.93	98.09	110.23	97.85	100.27	406.43	56.0%

Note: From others—directional spillover indices measure spillovers from all markets *j* to market *i*. Contribution to others—directional spillover indices measure spillovers from market *i* to all markets *j*. Contribution including own—directional spillover indices measure spillovers from market *i* to all markets *j* including contribution from own innovations of market *i*. Other columns contain net pairwise (*i,j*)th spillovers indices. Total volatility spillover index demonstrates that 56.0% of forecast error variance comes from spillovers. The mnemonics are defined as in Table 1.

picture of cross-region and region-specific information transmission. Moreover, the *Subtotal* rows capture total spillovers from market *i* to all markets *j* from a specific region, while the *Sum* columns demonstrate total spillovers from all markets *j* from a specific region to market *i*. Further discussion on some of the most important findings of our research to be essential to explain their theoretical and practical implications. This has been done below.

The Asian region is characterized by a lower level of spillovers between stock markets within the region compared to Europe and the Americas. The strongest return spillovers for all Asian markets come from the UK. In regard to volatility spillovers, UK influence is strongest mainly on the developed markets of Hong Kong, Japan, and Singapore. Similarly, these markets are influenced by shocks from markets from the Americas region, for example, the USA and Brazil. This could be explained by the fact that developed Asian markets are more integrated into the world economy when compared with emerging markets from the same region. The row *Contribution to Others* indicates that the Hong Kong stock market is the most influential in the Asian region (67.01% for returns and 50.38% for volatility). This, however, is mainly due to the high spillovers from Hong Kong to other Asian markets. Consequently, the intensity of intra-region spillovers is higher than the intensity of inter-regional spillovers. We found that the majority of Asian markets have the highest reaction to their own shocks, for example, Korea, Taiwan, and India record 93.94%, 96.90%, and 93.52% of their own forecast error variance respectively, making them the most independent markets in the sample. These results have a number of important implications. First, they reveal diversification opportunities in emerging Asian stock markets which are less affected by external shocks. Second, independence from external shocks limits the opportunities to predict the volatility of those markets based on foreign information transmission. As a result, emerging Asian markets seem to be an attractive option for portfolio investment strategy, but less attractive for investors utilizing an active trading strategy based on the meteor shower effect introduced by Engle et al. (1990).

While the Asian region is relatively independent from other regions, the linkages between Europe and the Americas are much stronger for both directions of spillovers, providing the evidence for inter-regional information transmission. However, developed markets are more influential than emerging markets. The strongest linkages between emerging and developed stock markets are within the Americas region, where the USA accounts for 11.03% and 10.04% of error variance of the stock market of Mexico and Brazil, respectively. One of the possible explanations for this phenomenon is that countries that are geographically close to each other have a higher level of volatility spillover because the geographical location affects the economic and financial integration of the countries. Among four countries selected from the Americas region, Canada is the least impacted upon by foreign information transmission.

The South African stock market is representative of the African region, and it is the third most influential emerging market in the sample after Mexico and Brazil. The greatest magnitude of spillovers is from South Africa to Russia (7.67% for return and 8.69% for volatility), while the magnitude of the reverse direction of spillovers is also high (6.58% for return and 7.90% for volatility). Additionally, South Africa has strong linkages with the UK stock market. South Africa also influences developed Asian markets and all four markets selected from Americas.

Overall, there is strong evidence of intra-regional and inter-regional returns spillovers across stock markets, while there is limited evidence of inter-regional volatility spillovers. The values of pairwise spillovers between markets from the same region are much higher than between markets from different regions. Furthermore, the magnitude of spillovers between developed and emerging stock markets is lower than between solely developed markets or emerging markets, which provides opportunities for international portfolio diversification.

4.2. Subsample analysis: comparison of evidence from futures and spot markets

A major contribution of this paper is the analysis of information transmission mechanisms across stock index futures, which are a practical and more realistic alternative to stock market indices in designing trading strategies. Spillover tables were compiled for the subsample period from October 4, 2010, to October 3, 2014, to allow a comparison of the magnitude of return and volatility spillovers across stock index futures and across stock market indices. Tables 6 and 7 provide evidence from futures markets for returns and volatility data, respectively, while Tables 8 and 9 provide evidence from underlying spot markets for the subsample period. The previous section explains the meaning of the rows and columns within the spillover tables and a similar interpretive logic of the empirical outputs is applicable for this section. As with the full-sample period, the magnitude of return spillovers is higher than the magnitude of volatility spillovers for both futures and spot markets. The total return spillover index is equal 66.3%, and the total volatility spillover index is 58.3% for stock index futures. Total spillovers indices for spot markets return and volatility are 65.5% and 52.0%, respectively. The return spillovers, therefore, across futures and spot markets are at the same level of magnitude, but the intensity of volatility spillovers is higher across futures. For example, Table 9 shows that Korea, Taiwan, and India have the lowest values of *Contribution to Others*, 4.77%, 2.03%, and 4.81% for volatility spillovers across stock market indices, while for stock index futures these values are 43.77%, 29.04%, and 34.28% (see Table 7). Volatility spillovers from Korea, Taiwan, and India, in relation to other markets are higher for futures data. This may be explained by lower cost of trading on futures markets and, therefore, the higher speed of international information transmission (Antoniou, Holmes & Priestley, 1998). Table 9 indicates that the total volatility spillover from the USA to other markets is 83.93%, while volatility spillover from the UK to other markets is 114.02%, making the UK much more influential than the USA. However, analysis of futures data reveals a different outcome and is presented in Table 7. The magnitude of volatility spillovers from the USA is higher than that from the UK, i.e. 104.01% and 101.01% respectively.

Again, as in the full-sample analysis, there are stronger financial linkages across markets from the same region in the subsample period for both futures and indices data. The strongest magnitude of volatility spillovers was found between developed European countries, UK, Germany, France, Spain, and Switzerland; developed Asian countries, Hong Kong and Singapore; and developed countries from the Americas, USA and Canada. The values of the pairwise spillovers indices are much lower between emerging markets within the sample. The linkages between emerging and developed markets are weaker, and in the majority of cases, the main direction of spillover of both return and volatility is from developed to emerging stock markets, for example, from Hong Kong to China, from the UK to South Africa, and from the USA to Mexico and Brazil. The intensity of intra-region volatility spillovers across stock index futures is higher than the intensity of inter-region volatility spillovers. The main channels of inter-regional information transmission are from the Americas to Europe and from Europe to the Americas. There is some evidence of inter-regional return spillovers from America and Europe to Asia. However, there is a very low magnitude of volatility spillovers from Asian countries to other regions. South Africa has strong spillovers into European markets. South Africa is from the same geographical time zone as European markets, and therefore, the trading hours of these markets overlap almost exactly. These channels of international information transmission are similar for both futures and stock indices. However, the magnitude of spillovers is higher for futures markets, so we can conclude that information transmission mechanisms work more efficiently in case of futures.

Nonetheless, the spillovers tables do not demonstrate additional significant differences between the information transmission mechanisms across futures markets (see Tables 6 and 7) and spot markets (see

Table 6
Return spillovers across stock index futures.

Region/ market		Asia									Europe and Africa										Americas					From others
		HKG	JPN	SGP	CHN	KOR	MYS	TWN	IND	Sum	GBR	GER	FRA	ESP	SUI	RUS	HUN	TUR	Sum	ZAF	CAN	USA	MEX	BRA	Sum	
Asia	HKG	40.01	3.56	9.98	7.36	4.51	3.67	4.91	5.41	79.40	4.26	1.02	1.43	0.36	1.04	3.93	1.43	0.66	14.14	1.19	1.62	2.85	2.72	3.17	5.28	59.99
	JPN	2.85	32.17	3.87	0.99	2.89	0.92	1.78	1.63	47.12	6.70	6.36	6.75	4.28	4.59	3.28	1.84	1.15	34.94	3.10	1.09	1.48	1.73	1.40	14.85	67.83
	SGP	5.63	2.42	22.35	1.90	4.50	3.52	2.96	4.28	47.56	5.96	4.54	4.63	2.57	3.63	4.33	2.37	1.51	29.54	2.16	2.59	2.82	2.23	2.45	20.75	77.65
	CHN	11.25	2.08	5.43	61.18	4.49	3.81	3.96	1.76	93.96	1.18	0.06	0.11	0.19	0.15	1.78	0.25	0.30	4.02	0.46	0.47	0.31	0.65	0.74	1.56	38.82
	KOR	3.09	2.43	5.22	1.74	23.83	1.88	5.38	2.76	46.33	5.16	5.15	5.05	3.99	3.42	4.19	2.62	1.59	31.16	2.31	0.14	0.06	0.06	0.05	20.19	76.17
	MYS	5.01	1.85	8.69	2.83	3.68	50.61	4.96	5.06	82.71	3.09	0.67	1.19	0.23	0.67	3.18	2.65	0.61	12.28	0.66	1.60	1.44	1.78	2.14	4.35	49.39
	TWN	6.00	2.71	6.68	3.56	11.28	5.00	48.78	3.17	87.19	2.78	0.05	0.27	0.09	0.08	2.09	1.22	0.12	6.69	0.35	0.07	0.09	0.19	0.12	5.76	51.22
	IND	4.91	1.40	7.32	0.97	3.24	4.30	2.13	37.96	62.25	5.07	2.97	3.39	1.65	2.36	4.45	2.37	1.42	23.68	2.40	0.06	0.18	0.11	0.21	11.68	62.04
Sub-total		78.76	48.62	69.55	80.54	58.43	73.72	74.86	62.03	546.51	34.19	20.82	22.82	13.35	15.93	27.23	14.76	7.35	156.44	12.64	17.14	38.92	13.21	15.15	84.41	483.10
Europe and Africa	GBR	1.87	0.65	2.39	0.35	1.32	1.17	1.04	2.38	11.19	18.32	10.70	11.52	6.31	8.79	5.26	3.87	2.88	67.64	6.22	3.35	8.51	1.61	1.48	14.95	81.68
	GER	0.43	0.04	0.66	0.02	0.09	0.36	0.02	1.42	3.05	11.44	19.26	15.63	10.00	9.83	4.59	4.49	2.97	78.20	6.05	3.00	7.32	1.07	1.29	12.69	80.74
	FRA	0.59	0.06	1.05	0.06	0.16	0.45	0.06	1.58	4.00	11.76	14.99	18.51	11.60	9.64	4.33	4.21	2.79	77.82	5.73	3.07	7.15	0.98	1.26	12.46	81.49
	ESP	0.09	0.05	0.28	0.07	0.03	0.06	0.14	0.92	1.64	9.06	13.47	16.21	25.69	7.84	3.37	4.43	2.59	82.67	4.59	2.61	6.48	0.70	1.32	11.11	74.31
	SUI	0.48	0.07	0.73	0.08	0.15	0.40	0.06	1.49	3.48	11.86	12.45	12.75	7.49	24.39	3.38	3.23	3.30	78.85	5.90	2.35	6.72	1.16	1.54	11.78	75.61
	RUS	2.73	1.16	4.00	0.64	2.75	1.63	1.11	3.16	17.17	7.76	6.40	6.29	3.47	3.66	26.86	6.13	2.87	63.45	5.31	3.18	6.83	1.72	2.34	14.06	73.14
	HUN	1.12	0.21	1.74	0.17	1.50	1.81	0.82	2.03	9.41	7.22	8.06	7.78	5.75	4.41	7.39	33.65	3.26	77.51	4.00	1.54	5.38	0.96	1.20	9.08	66.35
	TUR	0.90	0.15	1.50	0.12	0.51	0.58	0.41	1.79	5.96	6.44	6.44	6.36	4.32	5.84	4.49	4.16	42.45	80.50	4.11	1.91	4.00	1.54	1.98	9.43	57.55
Sub-total		8.21	2.40	12.35	1.52	6.51	6.46	3.67	14.79	55.90	83.86	91.77	95.05	74.64	74.40	59.66	64.16	63.10	606.64	41.92	21.01	52.39	9.74	12.40	95.55	590.87
	ZAF	0.84	0.04	1.17	0.20	0.49	0.42	0.17	2.11	5.43	10.16	9.44	9.23	5.28	7.13	5.73	3.36	2.86	53.19	28.62	3.36	5.43	2.13	1.84	71.38	71.34
Americas	CAN	0.50	0.02	0.76	0.10	0.46	0.11	0.31	0.71	2.98	6.40	5.54	5.94	3.60	3.25	2.56	1.66	1.46	30.41	3.78	35.95	14.48	5.62	6.77	62.83	64.05
	USA	0.93	0.33	1.67	0.14	1.41	0.89	1.07	1.62	8.05	10.15	8.26	8.54	5.48	5.89	4.55	3.43	2.04	48.35	3.97	8.79	21.84	4.60	4.39	39.63	78.16
	MEX	0.65	0.15	0.67	0.40	1.23	0.69	0.65	0.98	5.43	4.01	2.52	2.71	1.40	2.22	1.83	1.17	1.58	17.44	2.61	7.51	10.18	47.63	9.20	74.52	52.37
	BRA	0.32	0.21	0.39	0.15	0.69	0.22	0.33	0.59	2.90	3.74	2.95	3.21	2.41	2.87	1.83	1.60	1.47	20.08	2.40	8.85	9.51	9.06	47.20	74.63	52.80
Sub-total		2.40	0.71	3.48	0.79	3.79	1.90	2.37	3.90	19.35	24.30	19.27	20.40	12.89	14.23	10.78	7.87	6.55	116[illegible]	12.76	61.11	56.02	66.92	67.56	251.61	247.37
Contr to others*		50.19	19.60	64.20	21.86	45.39	31.90	32.28	44.87	310.29	134.20	122.03	128.99	80.47	87.29	76.53	56.50	37.41	723.42	67.32	66.66	130.91	44.37	49.76	291.71	1392.73
Contr incl own**		90.20	51.77	86.55	83.05	69.22	82.51	81.06	82.83	627.19	152.51	141.29	147.50	106.16	111.68	103.39	90.15	79.86	932.55	95.93	102.61	152.76	92.00	96.96	444.33	66.3%

Note: From others—directional spillover indices measure spillovers from all markets *j* to market *i*. Contribution to others—directional spillover indices measure spillovers from market *i* to all markets *j*. Contribution including own—directional spillover indices measure spillovers from market *i* to all markets *j* including contribution from own innovations of market *i*. Other columns contain net pairwise (*i,j*)th spillovers indices. Total return spillover index demonstrates that 66.3% of forecast error variance comes from spillovers. The mnemonics are defined as in Table 1.

Table 7
Volatility spillovers across stock index futures.

Region/ market		Asia									Europe and Africa										Americas					From others
		HKG	JPN	SGP	CHN	KOR	MYS	TWN	IND	Sum	GBR	GER	FRA	ESP	SUI	RUS	HUN	TUR	Sum	ZAF	CAN	USA	MEX	BRA	Sum	
Asia	HKG	51.06	2.69	12.45	6.43	4.13	3.06	3.52	6.01	89.36	1.14	0.53	0.70	0.15	0.43	2.48	0.73	0.21	6.37	0.82	1.07	0.96	0.66	0.77	3.45	48.94
	JPN	2.43	53.25	3.32	1.84	5.06	1.63	2.90	0.89	71.32	3.07	3.12	2.95	2.25	1.91	2.01	1.45	0.60	17.36	1.37	2.50	5.17	0.40	1.88	9.96	46.75
	SGP	9.62	2.46	39.40	2.09	4.94	4.63	2.85	4.60	70.60	1.79	2.10	2.19	1.65	2.03	3.70	1.50	0.42	15.40	1.53	2.71	5.34	1.64	2.79	12.47	60.60
	CHN	8.89	2.89	3.90	71.65	4.36	2.15	2.57	1.07	97.49	0.10	0.05	0.04	0.23	0.18	0.69	0.07	0.19	1.55	0.24	0.14	0.29	0.25	0.04	0.72	28.35
	KOR	3.61	4.41	5.48	2.67	42.97	1.81	10.45	2.26	73.66	1.93	2.00	1.80	1.67	0.97	2.62	1.62	0.70	13.32	1.10	3.22	4.73	1.72	2.25	11.92	57.03
	MYS	3.82	2.21	7.44	1.18	2.91	64.48	2.92	4.39	89.35	0.67	0.29	0.64	0.31	0.43	2.80	1.57	0.16	6.86	0.45	0.22	1.26	1.28	0.58	3.34	35.52
	TWN	3.85	3.51	4.26	2.21	14.31	2.65	59.61	2.09	92.48	0.69	0.15	0.32	0.38	0.43	0.93	0.27	0.14	3.32	0.51	0.91	2.01	0.34	0.42	3.69	40.39
	IND	6.20	0.81	7.08	0.62	2.08	4.72	1.23	53.60	76.34	2.49	1.88	2.52	1.18	1.75	4.01	1.50	0.64	15.98	2.36	1.25	1.83	1.15	1.09	5.32	46.40
Sub-total		89.49	72.23	83.32	88.70	80.75	85.13	86.05	74.92	660.59	11.89	10.11	11.16	7.82	8.13	19.25	8.72	3.07	80.16	8.38	17.14	38.92	13.21	15.15	50.87	364.00
Europe and Africa	GBR	0.52	0.34	0.85	0.04	0.61	0.36	0.22	1.09	4.02	22.78	14.25	13.84	8.63	11.21	5.09	4.26	2.84	82.91	5.99	1.42	4.20	0.68	0.78	7.08	77.22
	GER	0.21	0.03	0.38	0.02	0.13	0.24	0.02	0.97	2.00	13.58	21.19	16.19	10.85	10.08	5.03	4.61	2.81	84.33	5.56	1.65	4.98	0.70	0.77	8.10	78.81
	FRA	0.26	0.10	0.68	0.03	0.15	0.22	0.03	1.00	2.47	12.56	15.64	20.48	12.99	9.64	5.20	4.64	2.98	84.14	5.59	1.69	4.72	0.68	0.71	7.80	79.52
	ESP	0.06	0.04	0.23	0.01	0.07	0.08	0.06	0.63	1.18	9.93	13.20	16.24	25.49	7.81	4.11	5.17	2.78	84.72	4.35	2.07	5.48	0.91	1.29	9.75	74.51
	SUI	0.19	0.20	0.52	0.07	0.32	0.21	0.03	1.04	2.57	13.61	12.79	12.65	8.16	26.82	4.25	3.77	3.32	85.36	5.28	1.09	4.13	0.70	0.86	6.79	73.18
	RUS	1.53	0.63	2.57	0.27	1.30	1.38	0.40	2.29	10.38	7.16	7.57	8.14	5.17	4.85	31.53	5.74	3.09	73.25	7.22	2.21	4.35	1.09	1.50	9.15	68.47
	HUN	0.38	0.06	0.45	0.05	0.34	0.90	0.17	1.36	3.70	7.36	8.26	8.35	7.37	5.14	6.51	35.55	3.98	82.51	6.01	1.33	4.28	0.85	1.33	7.79	64.45
	TUR	0.16	0.14	0.24	0.18	0.16	0.10	0.14	0.76	1.89	5.71	6.52	7.10	5.39	5.98	4.42	5.19	47.43	87.75	4.87	1.01	2.84	0.85	0.80	5.50	52.57
Sub-total		3.32	1.52	5.93	0.66	3.08	3.50	1.06	9.14	28.21	92.68	99.43	102.99	84.05	81.53	66.13	68.93	69.23	664.97	44.87	21.01	52.39	9.74	12.40	61.96	568.73
	ZAF	0.53	0.07	0.87	0.07	0.29	0.39	0.08	1.55	3.86	8.81	8.58	8.85	5.47	6.36	7.41	5.26	3.15	53.19	32.42	2.27	4.07	1.95	1.53	9.82	67.58
Americas	CAN	0.43	0.23	0.49	0.04	0.38	0.14	0.54	0.37	2.62	2.31	3.10	3.24	3.35	1.33	1.91	1.64	0.74	17.62	2.05	42.20	19.80	7.75	7.95	77.71	57.80
	USA	0.30	0.20	0.72	0.11	0.84	0.40	0.49	0.77	3.83	5.29	6.68	6.72	6.28	3.99	3.76	3.19	1.70	37.62	3.31	13.51	29.02	6.13	6.59	55.24	70.98
	MEX	0.35	0.07	0.17	0.16	0.68	0.41	0.19	0.66	2.69	1.10	1.44	1.45	1.88	0.91	1.38	1.31	0.80	10.29	1.72	10.07	11.74	53.66	9.82	85.30	46.34
	BRA	0.47	0.20	0.31	0.17	0.72	0.23	0.24	0.47	2.80	1.69	1.70	1.71	2.52	1.49	1.37	1.81	0.56	12.86	1.57	9.78	11.81	9.18	52.01	82.77	47.99
Sub-total		1.55	0.70	1.68	0.48	2.62	1.18	1.46	2.27	11.94	10.40	12.93	13.12	14.04	7.72	8.42	7.95	3.80	78.39	8.65	61.11	56.02	66.92	67.56	301.03	223.11
Contr to others*		43.83	21.27	52.42	18.27	43.77	25.72	29.04	34.28	268.59	101.01	109.86	115.64	85.89	76.92	69.68	55.31	31.82	646.13	61.90	60.13	104.01	38.90	43.76	246.79	1223.41
Contr incl own**		94.89	74.52	91.81	89.91	86.74	90.20	88.64	87.87	704.60	123.79	131.05	136.13	111.38	103.74	101.21	90.86	79.24	877.41	94.32	102.33	133.03	92.56	95.76	423.68	58.3%

Note: From others—directional spillover indices measure spillovers from all markets *j* to market *i*. Contribution to others—directional spillover indices measure spillovers from market *i* to all markets *j*. Contribution including own—directional spillover indices measure spillovers from market *i* to all markets *j* including contribution from own innovations of market *i*. Other columns contain net pairwise (*i*,*j*)th spillovers indices. Total volatility spillover index demonstrates that 58.3% of forecast error variance comes from spillovers. The mnemonics are defined as in Table 1.

Table 8
Return spillovers across stock markets subsample.

Region/	market	Asia									Europe and Africa										Americas					From others
		HKG	JPN	SGP	CHN	KOR	MYS	TWN	IND	Sum	GBR	GER	FRA	ESP	SUI	RUS	HUN	TUR	Sum	ZAF	CAN	USA	MEX	BRA	Sum	
Asia	HKG	37.63	3.18	10.47	8.70	5.77	2.81	5.80	2.46	76.82	4.29	0.42	0.62	0.20	0.48	3.71	0.59	0.24	10.54	4.32	0.64	2.17	2.63	2.88	8.32	62.37
	JPN	4.70	58.50	4.05	1.49	7.24	3.05	5.87	0.36	85.26	3.09	0.56	0.68	0.27	0.38	2.62	0.06	0.02	7.67	3.61	0.06	1.40	1.46	0.54	3.47	41.50
	SGP	10.29	2.56	37.26	3.16	4.59	3.06	5.02	3.09	69.04	5.86	1.95	2.07	0.79	1.87	4.75	0.74	0.52	18.55	4.18	0.71	3.29	2.14	2.09	8.24	62.74
	CHN	13.33	2.09	5.15	57.20	3.47	2.39	4.26	0.85	88.73	1.50	0.11	0.11	0.28	0.05	1.91	0.10	0.05	4.12	3.10	0.50	0.68	1.68	1.19	4.04	42.80
	KOR	6.33	4.84	5.49	2.60	40.85	3.03	10.04	1.43	74.61	4.10	0.61	0.74	0.36	0.74	3.83	0.76	0.44	11.59	3.31	1.07	3.70	3.12	2.60	10.48	59.15
	MYS	4.01	2.60	3.54	1.67	3.32	53.66	4.38	1.78	74.96	2.65	1.87	1.92	0.78	1.34	2.45	1.53	0.74	13.28	1.48	1.51	2.34	3.77	2.65	10.27	46.34
	TWN	7.04	4.76	5.92	3.47	11.19	3.50	45.40	1.71	83.00	2.47	0.15	0.21	0.37	0.10	2.49	0.16	0.11	6.06	3.33	0.87	3.01	1.69	2.03	7.61	54.60
	IND	3.26	0.36	4.19	0.56	1.13	1.26	1.23	51.69	63.68	5.56	2.59	3.22	1.78	2.53	3.64	1.16	1.35	21.82	4.68	1.11	3.07	2.89	2.76	9.83	48.31
Sub-total		86.59	78.89	76.06	78.85	77.56	72.76	82.00	63.37	616.09	29.52	8.26	9.56	4.84	7.49	25.39	5.10	3.46	93.63	28.01	6.47	19.66	19.38	16.76	62.27	417.80
Europe and Africa	GBR	1.89	0.85	2.67	0.41	1.44	0.50	0.94	1.41	10.10	16.96	8.87	9.51	5.71	7.63	5.75	2.81	2.58	59.82	7.75	3.12	9.27	4.94	5.00	22.32	83.04
	GER	0.31	0.04	0.79	0.03	0.20	0.04	0.09	0.84	2.33	9.63	18.51	15.28	10.33	10.28	4.47	4.62	3.61	76.71	4.74	1.92	7.36	3.72	3.22	16.22	81.49
	FRA	0.34	0.03	0.90	0.04	0.18	0.05	0.06	0.95	2.56	9.99	14.72	17.85	12.27	10.35	4.05	4.26	3.28	76.76	4.44	1.81	7.22	3.73	3.49	16.24	82.15
	ESP	0.14	0.01	0.39	0.08	0.09	0.01	0.19	0.77	1.68	8.02	13.35	16.50	23.94	8.71	3.31	4.92	3.34	82.10	3.03	1.43	5.92	2.68	3.15	13.18	76.06
	SUI	0.29	0.09	0.95	0.06	0.40	0.09	0.10	0.89	2.86	9.96	12.40	12.95	8.09	22.44	3.61	3.84	3.65	76.93	4.83	1.82	6.62	3.60	3.33	15.38	77.56
	RUS	2.60	1.03	3.23	0.74	1.87	0.87	1.38	1.47	13.20	8.74	6.17	5.82	3.54	4.11	25.36	4.22	2.14	60.11	7.21	2.30	7.28	4.78	5.11	19.47	74.64
	HUN	0.57	0.02	0.53	0.01	0.53	0.35	0.13	0.90	3.04	6.10	9.16	8.79	7.27	6.30	5.71	35.64	3.59	82.56	3.99	0.68	4.05	3.05	2.63	10.41	64.36
	TUR	0.25	0.04	0.54	0.06	0.22	0.14	0.20	0.93	2.37	6.10	8.03	7.70	5.85	6.92	3.48	4.06	41.24	83.38	3.85	0.75	3.58	2.94	3.13	10.40	58.76
Sub-total		6.38	2.11	10.01	1.43	4.92	2.06	3.08	8.16	38.14	75.50	91.22	94.40	76.99	76.75	55.74	64.35	63.43	598.39	39.85	13.83	51.29	29.45	29.06	123.63	598.06
	ZAF	2.39	1.51	2.57	1.12	1.72	0.57	1.60	1.97	13.44	10.54	5.91	5.75	2.93	5.05	6.56	2.51	2.18	41.44	22.94	3.92	7.35	5.60	5.31	22.19	77.06
Americas	CAN	0.61	0.04	0.77	0.39	0.58	0.22	0.55	0.62	3.78	5.20	4.30	4.15	2.51	3.26	1.37	0.80	0.75	22.33	2.93	41.20	14.18	8.11	7.47	70.95	58.80
	USA	1.04	0.40	1.68	0.28	1.34	0.37	1.18	1.01	7.30	9.76	7.77	8.13	4.96	5.80	4.72	2.19	1.67	45.00	4.98	6.96	20.30	8.28	7.18	42.73	79.70
	MEX	1.90	0.59	1.39	0.69	1.93	0.83	0.89	1.29	9.52	7.16	5.28	5.58	2.99	4.22	4.41	2.29	1.80	33.73	5.47	5.26	11.09	26.83	8.10	51.28	73.17
	BRA	2.06	0.23	1.27	0.67	1.58	0.43	1.05	1.45	8.73	7.49	4.88	5.50	3.70	4.17	4.41	2.10	1.95	34.19	4.81	5.17	10.12	8.54	28.43	52.26	71.57
Sub-total		5.61	1.25	5.12	2.03	5.42	1.86	3.66	4.37	29.33	29.60	22.23	23.36	14.16	17.45	14.91	7.37	6.17	135.25	18.20	58.58	55.69	51.77	51.18	217.23	283.23
Contr to others*		63.34	25.26	56.50	26.22	48.77	23.59	44.94	26.18	314.80	128.19	109.11	115.23	74.98	84.31	77.24	43.70	34.00	666.76	86.06	41.60	113.69	79.37	73.88	308.54	1376.16
Contr incl own**		100.97	83.76	93.75	83.42	89.62	77.25	90.34	77.87	697.00	145.16	127.62	133.08	98.92	106.75	102.60	79.34	75.24	868.70	108.99	82.80	134.00	106.21	102.31	425.31	65.5%

Note: From Others—directional spillover indices measure spillovers from all markets *j* to market *i*. Contribution to others—directional spillover indices measure spillovers from market *i* to all markets *j*. Contribution including own—directional spillover indices measure spillovers from market *i* to all markets *j* including contribution from own innovations of market *i*. Other columns contain net pairwise (*i,j*)th spillovers indices. Total return spillover index demonstrates that 65.5% of forecast error variance comes from spillovers. The mnemonics are defined as in Table 1.

Table 9
Volatility spillovers across stock markets subsample.

Region/market		Asia									Europe and Africa										Americas					From others
		HKG	JPN	SGP	CHN	KOR	MYS	TWN	IND	Sum	GBR	GER	FRA	ESP	SUI	RUS	HUN	TUR	Sum	ZAF	CAN	USA	MEX	BRA	Sum	
Asia	HKG	57.21	2.73	12.73	9.09	0.12	3.67	0.10	0.02	85.67	1.33	0.35	0.64	0.14	0.35	2.86	0.51	0.13	6.31	2.48	1.79	1.06	1.13	1.55	5.54	42.79
	JPN	3.04	78.98	3.22	1.89	0.04	3.17	0.27	0.07	90.68	1.91	0.33	0.69	0.35	0.73	1.66	0.08	0.06	5.82	1.52	0.73	0.62	0.52	0.11	1.98	21.02
	SGP	12.08	2.67	54.51	3.19	0.19	2.86	0.05	0.04	75.59	3.20	1.77	2.37	1.03	2.09	4.15	0.45	0.33	15.38	3.00	1.79	2.50	0.80	0.94	6.03	45.49
	CHN	11.63	2.50	4.67	73.44	0.11	1.98	0.05	0.60	94.97	0.36	0.07	0.19	0.33	0.09	1.05	0.22	0.07	2.39	1.17	0.48	0.31	0.53	0.15	1.47	26.56
	KOR	0.17	0.21	0.19	0.20	93.09	0.97	0.03	1.85	96.70	0.24	0.17	0.19	0.10	0.04	0.34	0.06	0.22	1.35	0.23	0.52	0.41	0.47	0.32	1.71	6.91
	MYS	4.66	3.24	3.12	1.52	0.68	77.42	0.37	0.07	91.08	0.91	0.06	0.25	0.04	0.30	2.56	0.70	0.40	5.21	0.39	0.61	0.61	1.30	0.80	3.32	22.58
	TWN	0.22	0.05	0.14	0.05	0.54	0.06	95.47	0.16	96.69	0.19	0.13	0.31	0.48	0.14	0.44	0.21	0.27	2.17	0.07	0.18	0.26	0.39	0.24	1.07	4.53
	IND	0.12	0.39	0.30	0.02	1.28	0.38	0.48	93.16	96.12	0.52	0.61	0.74	0.27	0.49	0.32	0.14	0.05	3.15	0.13	0.24	0.15	0.11	0.10	0.60	6.84
Sub-total		89.13	90.76	78.88	89.40	96.05	90.51	96.82	95.97	727.50	8.65	3.50	5.37	2.73	4.24	13.38	2.37	1.53	41.78	9.01	6.34	5.92	5.26	4.19	21.71	176.73
Europe and Africa	GBR	0.61	0.44	1.16	0.09	0.05	0.22	0.01	0.16	2.72	19.03	12.57	13.31	8.89	11.27	5.31	2.75	3.08	76.20	6.96	3.72	5.55	2.20	2.65	14.12	80.97
	GER	0.18	0.04	0.68	0.03	0.11	0.06	0.01	0.13	1.22	12.63	18.80	16.18	11.64	10.90	4.66	3.44	2.97	81.21	5.22	3.04	5.23	1.98	2.09	12.34	81.20
	FRA	0.25	0.11	0.84	0.04	0.10	0.06	0.00	0.16	1.56	12.72	15.46	18.09	12.94	10.76	4.69	3.29	2.91	80.86	5.26	3.04	5.06	1.99	2.23	12.32	81.91
	ESP	0.08	0.06	0.48	0.03	0.11	0.02	0.04	0.07	0.89	10.95	14.38	16.68	23.26	9.24	3.94	3.62	2.85	84.93	3.92	2.54	4.16	1.53	2.03	10.26	76.74
	SUI	0.18	0.19	0.84	0.04	0.07	0.11	0.02	0.19	1.64	13.19	12.67	13.11	8.70	21.92	4.22	2.81	3.57	80.19	5.33	3.16	5.21	1.96	2.51	12.84	78.08
	RUS	1.60	0.63	2.30	0.36	0.24	0.85	0.07	0.15	6.20	8.59	7.60	7.96	5.23	5.80	30.52	4.81	3.44	73.94	7.88	2.71	4.11	2.31	2.85	11.98	69.48
	HUN	0.28	0.00	0.41	0.05	0.36	0.40	0.03	0.41	1.95	6.55	7.80	7.68	6.40	5.32	6.46	39.99	3.88	84.08	5.41	1.18	3.28	1.93	2.17	8.56	60.01
	TUR	0.17	0.11	0.24	0.07	0.29	0.21	0.09	0.04	1.23	7.24	7.13	7.47	5.71	7.47	4.92	4.18	43.46	87.59	5.01	0.88	2.16	1.39	1.74	6.17	56.54
Sub-total		3.35	1.58	6.95	0.71	1.31	1.93	0.26	1.31	17.41	90.90	96.41	100.48	82.78	82.68	64.72	64.87	66.17	649.01	44.99	20.26	34.77	15.29	18.28	88.60	584.93
	ZAF	1.10	0.64	1.53	0.34	0.09	0.13	0.11	0.25	4.20	10.65	8.05	8.41	4.96	7.09	7.45	3.84	3.34	53.79	29.32	3.10	3.77	3.30	2.53	42.01	70.68
Americas	CAN	0.78	0.28	1.01	0.20	0.02	0.15	0.12	0.20	2.75	5.93	5.40	5.53	3.57	4.52	2.10	0.94	0.68	28.67	2.56	33.97	16.85	7.66	7.53	66.01	66.03
	USA	0.36	0.18	0.85	0.11	0.10	0.17	0.07	0.01	1.86	7.54	7.33	7.58	4.79	6.15	3.30	1.88	1.14	39.70	2.92	13.39	26.94	7.47	7.71	55.51	73.06
	MEX	0.80	0.28	0.33	0.44	0.18	0.43	0.08	0.08	2.63	4.24	4.15	4.34	2.55	3.40	2.73	1.79	1.15	24.34	3.69	9.17	11.33	40.31	8.53	69.34	59.69
	BRA	0.99	0.12	0.49	0.11	0.11	0.30	0.04	0.16	2.33	5.13	4.25	4.73	3.29	4.19	2.66	1.96	1.33	27.54	2.21	8.90	11.29	8.19	39.53	67.92	60.47
Sub-total		2.94	0.86	2.69	0.86	0.41	1.06	0.31	0.45	9.57	22.84	21.12	22.18	14.19	18.25	10.80	6.56	4.31	120.25	18.20	11.39	65.44	66.41	63.64	258.79	259.24
Contr to others*		39.31	14.86	35.53	17.88	4.77	16.20	2.03	4.81	135.40	114.02	110.27	118.36	81.40	90.35	65.82	37.66	31.89	649.76	65.38	61.17	83.93	47.17	48.76	241.03	1091.58
Contr incl own**		96.53	93.84	90.04	91.31	97.87	93.62	97.50	97.98	758.68	133.05	129.08	136.45	104.66	112.27	96.34	77.65	75.35	864.84	94.70	95.14	110.87	87.49	88.30	381.79	52.0%

Note: From others—directional spillover indices measure spillovers from all markets *j* to market *i*. Contribution to others—directional spillover indices measure spillovers from market *i* to all markets *j*. Contribution including own—directional spillover indices measure spillovers from market *i* to all markets *j* including contribution from own innovations of market *i*. Other columns contain net pairwise (*i*,*j*)th spillovers indices. Total return spillover index demonstrates that 52.0% of forecast error variance comes from spillovers. The mnemonics are defined as in Table 1.

Table 10
Structural breaks, full sample.

	Market	HKG	JPN	SGP	CHN	KOR	MYS	TWN	IND	GBR	GER	FRA	ESP	SUI	RUS	HUN	ZAF	TUR	CAN	USA	MEX	BRA
2005	Futures			11:18																11:02		
2006	Spot		08:14	05:05 07:27	05:05 07:19	07:10	05:17 07:26 11:06	05:08 06:20 09:18	05:12 06:16 07:27 12:07	05:11 08:07	05:10 08:15	05:11 05:31 08:15	05:11 05:31	05:02 05:31 08:15	05:11 07:13	05:16 07:17	05:12 06:15 09:11	05:11 07:20		05:10 07:28	05:16 07:20	07:24
2007	Futures	01:01 03:12 07:31	04:19 08:14 09:19	01:19 04:19 07:06 08:14 08:22	01:05 08:03	07:25	02:23 03:08 05:24 07:30 08:23	07:25	02:22 04:16 07:26	07:23	02:26	07:09 09:18	04:19 09:19	07:18		11:16	07:24	07:11	10:17	02:26 03:21 07:23	02:23 03:21 11:02	07:23
2008	Spot	01:08 03:28 09:16 11:07	01:03 03:17 10:03 10:30 12:15	01:11 03:25 09:10 11:07	01:18 12:12	02:04 07:01 10:15 12:10	01:03 03:03 04:03 09:10 11:03	06:19 10:27 12:24	01:17 03:31 10:02 11:21	09:02 11:24	01:14 02:18 09:26 12:02	01:14 02:15 09:16 12:09	01:14 02:06 05:30 09:16 12:02	01:03 02:15 09:15 12:01	01:15 02:12 07:16 09:15 11:25	02:18 09:16 11:14	09:04 12:10	09:10 12:03	09:05 12:01	09:12 12:05	03:14 09:16 12:01	09:08 11:24
2009	Futures	05:06 12:17	05:07	05:11 08:31	07:28 09:28	04:29 12:04	08:24	07:13	08:24	04:03 12:01	04:02 12:01	07:02	05:18	05:18	08:03	07:15	07:15	05:20	03:02 06:25 12:04	04:21 11:09	05:08 12:02	05:18
2010	Spot		10:12	01:25 07:07		10:08		07:06		04:26 05:27 09:01	04:26 05:20 09:24	04:26 10:05	01:18 05:03 05:14 07:07	09:24	05:03 07:06	06:10	04:27 05:27 09:01	05:06 05:26 11:19	05:14 07:21	04:26 09:01	04:26 09:01	07:07
2011	Futures	08:09 11:16	03:11 04:08	08:01 11:02	02:22	08:01 10:05	08:05 10:18	08:03 11:25		08:02 10:06 12:14	07:29 12:21	07:29 08:18 12:21	01:18 06:09 07:29 08:12 12:12	08:01 09:06 12:20	08:02 12:12	07:28 12:01	01:10 08:03 11:30	08:03 12:12	01:25 07:25 10:07	05:30 08:03 08:23 12:20	08:01 09:26	08:01 10:27
2012	Spot	07:24	12:17	08:03		01:06	01:05	07:31	03:26	08:03	09:11	04:02 08:07	04:12 09:06		05:03 10:01	06:25	10:01	08:03	06:21		01:18	09:13
2013	Futures		05:22 06:17 08:08	04:22 07:25	07:23	07:11	01:18 09:10	11:21	02:25 08:15 10:18	05:22 07:09		07:08	07:18	04:01 07:05			04:02 07:11	01:24 02:11 05:31 07:15 12:16		06:24	03:12 10:15	05:28
2014	Spot		04:16					04:24						01:23 03:25	02:12 03:18		02:17	02:06			03:21	

Note: The date of structural break in volatility is displayed as month: day. The mnemonics are defined as in Table 1.

Table 11
Structural breaks, subsample.

Y	Market	HKG	JPN	SGP	CHN	KOR	MYS	TWN	IND	GBR	GER	FRA	ESP	SUI	RUS	HUN	ZAF	TUR	CAN	USA	MEX	BRA
2010	Futures					12:09																
	Spot		11:19													11:09 12:07						
2011	Futures	08:08 11:17	03:09 03:23 07:29 12:19	07:29 12:09	02:22 08:05	02:08 08:01 12:21	04:14 08:05 12:06	08:03 11:25		08:03 08:18 12:14	07:29 12:12	07:29 12:14	01:27 07:29 12:12	08:01 09:06	08:02 12:12	07:29 10:10	08:03 11:30	07:21 08:19	07:25 12:14	07:29 11:30	07:28 10:19	07:29 12:20
	Spot	08:09 11:16	03:11 04:08	08:01 11:02	02:22	08:01 11:29	08:05	08:03 11:25		08:02 10:06 12:14	07:29 12:12	07:29 08:18 12:21	01:18 07:29 12:12	08:01 09:06 12:20	08:02 12:12	07:28 12:01	08:01 11:30	07:21 12:12	03:04 08:01 10:07 12:30	05:30 08:01 08:23 12:20	08:01 09:26	08:01 10:27
2012	Futures	07:23		07:24	02:08 12:04	05:15 09:14		07:12	06:19	03:30 08:03	08:03	04:12 08:07	04:12 09:06	02:03	10:01	01:26 09:14	08:03	02:01 08:03	08:07	05:16 08:03	07:31	
	Spot	07:24	12:17	08:03			01:05	07:31	06:19	03:30 08:03	08:06	04:02 08:07	04:12 09:06		05:03 10:01	06:25	10:01	08:03	05:02 07:10		01:18	09:13
2013	Futures	03:01 09:05	01:03 05:22 06:13 08:20	04:22 09:30	07:23		01:18 09:12	10:08	02:20 08:05 10:03	04:01 09:03		07:08	07:18	04:01 07:04	04:08 07:18	06:06 08:28	04:02 09:02	01:24 02:07 05:28 07:08	03:20 08:30	06:26	05:22 10:03	
	Spot		05:22 06:17 08:08	04:22 07:25	07:23	07:11	01:18 09:10	11:21	02:25 08:15 10:18	05:22 07:09	07:08	07:08 12:02	07:18	04:01 07:05	04:08 07:12		04:02 07:11	01:24 02:11 05:31 07:15 12:16		06:24	03:12 10:15	05:28
2014	Futures		01:03 04:16		04:15 07:21	02:04		04:24				07:04		01:02 03:25	02:26 05:07			03:28			03:21	
	Spot		04:16					04:24			01:01	03:25 07:02		01:23 03:25	02:25 03:18		02:17	02:06			03:21	

Note: The date of structural break in volatility is displayed as month: day. The mnemonics are defined as in Table 1.

Tables 8 and 9) apart from those discussed above. Additionally, we cannot use spillovers tables to observe the dynamic of return and volatility spillovers during the full-sample and subsample estimation periods. We have to consider the contagion across markets to provide a clear picture of the behavior of spillovers during periods of turmoil, which can further explain some of our findings outlined earlier. For example, the high intensity of spillovers across developed European countries can be explained by contagion between those markets during the Eurozone crisis. It is useful, therefore, to plot return and volatility spillovers to investigate the behavior of spillovers across futures and stock indices around the most recent crisis episodes.

4.3. Structural breaks

In this section, the issue of whether there is evidence of structural breaks in the dynamics of stock indices and futures returns volatility is examined. The existence of structural breaks is a classical statistical problem which affects volatility and long-range dependence in stock returns (Andreou & Ghysels, 2002). Omitting structural breaks in an analysis of volatility spillovers may lead to a significant overestimation of volatility transmission because jumps in volatility can influence information flow in relation to intensity, direction, origin, and the scheme of transmission (Huang, 2012). The iterated cumulative sum of squares (ICSS) algorithm introduced by Inclan and Tiao (1994) has been employed to test for multiple breaks in the volatility of spot and futures markets for each country separately.

The test on structural shifts is used often to identify the crisis period (Dimitriou, Kenourgios & Simos, 2013; Karanasos et al., 2014). In this paper, the identified structural breaks are linked to the major shocks during the Great Recession and the European debt crisis. These results are consistent with the timeline of the global financial crisis provided by BIS (2009), which is used in this study. The structural changes in variance do not occur exactly simultaneously in futures and spot markets, although certain similarities in breaks across markets are found, especially, between markets within the same geographical region around crisis episodes. This provides additional evidence of strong intra-region market dependencies.

Tables 10 and 11 summarize the results of the Inclan and Tiao (1994) test and indicate the existence of multiple structural breaks in the dynamics of volatility over both the full-sample and the subsample periods. All the return series have at least 10 structural breaks in their variance over the full-sample period and at least one structural break over the subsample period, but the number of jumps in variance varies from year to year as demonstrated in Tables 10 and 11.

4.4. Rolling-sample analysis

The behavior of total return and volatility spillovers around the global financial crisis and the European debt crisis is investigated in this section. We used rolling window estimation to analyze the time-varying behavior of spillovers over the full-sample and subsample periods. It is important to consider cyclical movements and burst in spillovers that could not be captured by the results presented in previous tables. We compared the behavior of return and volatility spillovers across stock index futures and stock equity indices for the subsample period. Fig. 1 presents the spillover plot for stock index futures and stock indices data from October 2010 to October 2014 based on the 200-day rolling window estimation following the methodology developed by Diebold and Yilmaz (2012). While the cyclical movements of spillovers are similar for futures and spot markets, the magnitude of spillovers is higher for futures markets during the subsample period, confirming the findings discussed in the previous section. Fig. 1 provides information that confirms that the magnitude of volatility spillovers is lower than the magnitude of return spillovers for both futures and spot markets. The significant increase in total spillovers during 2011 was caused by the European debt crisis, while from 2012 to 2014, we can see a decrease in spillovers across futures and spot markets, which can be interpreted as a sign of the global economic recovery.

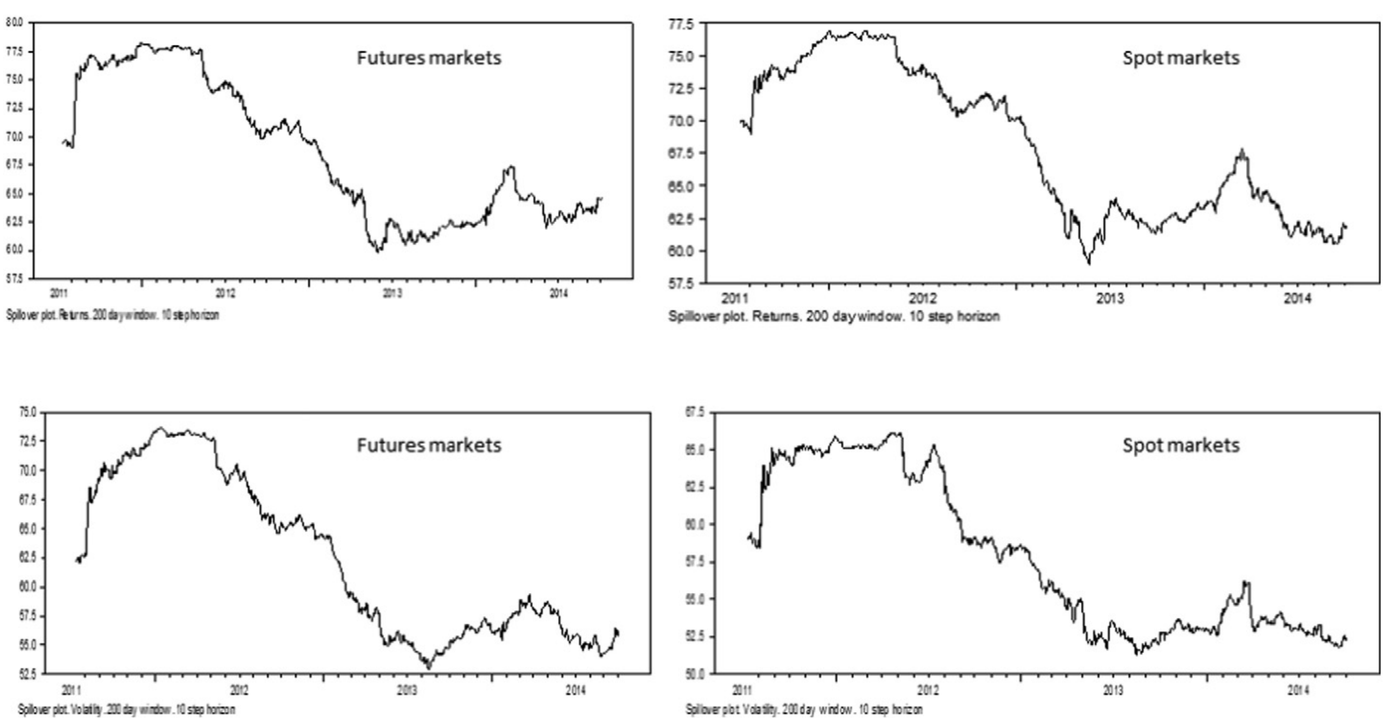

Fig. 1. Subsample total spillovers plot: futures and spot markets.

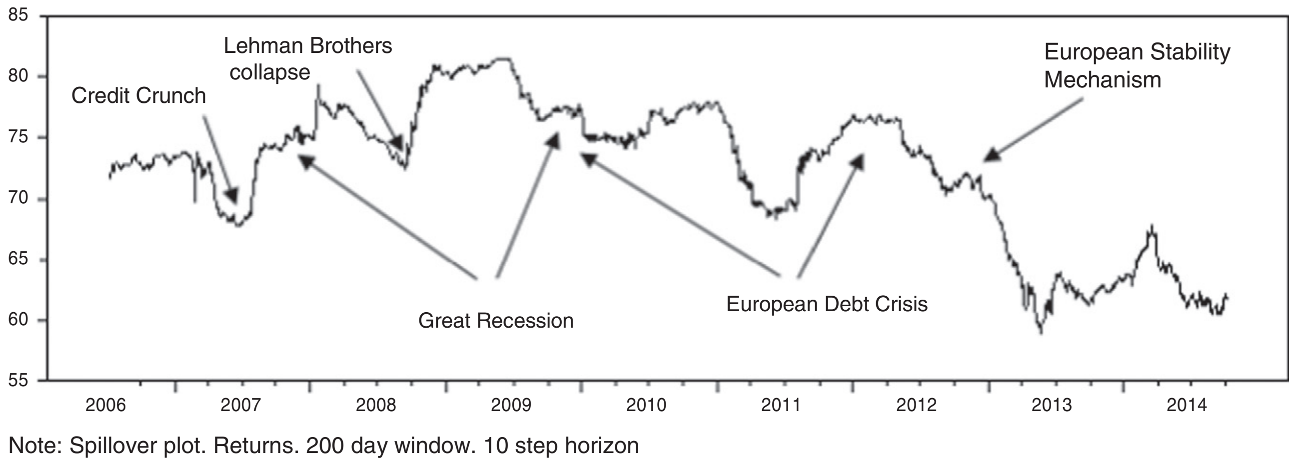

Fig. 2. Return spillover plot, stock indices, full sample.

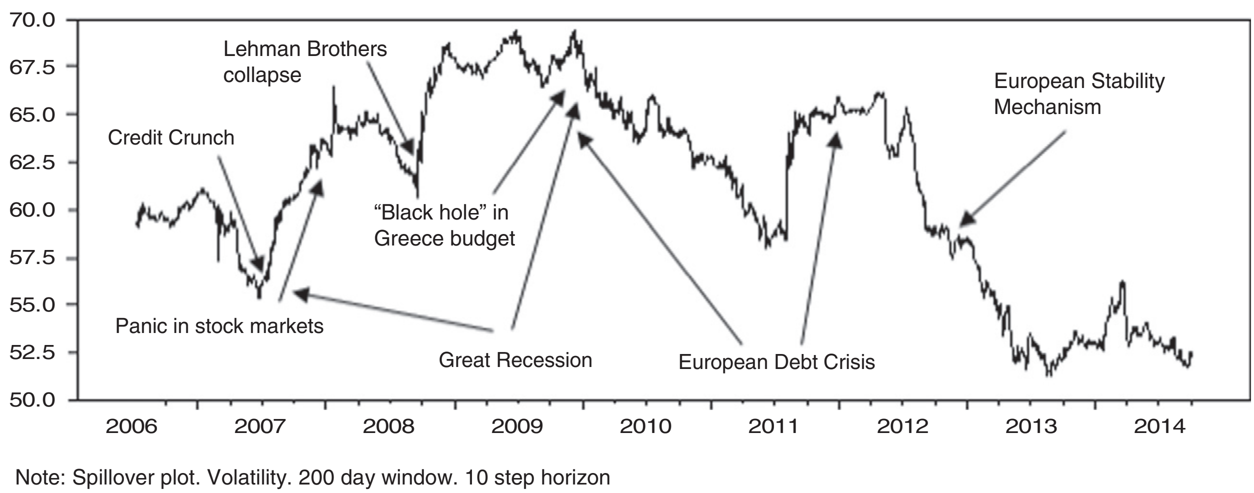

Fig. 3. Volatility spillover plot, stock indices, full sample.

Fig. 2 presents the return spillover plot for stock indices data from 2005 to 2014.

Several cycles are identified from October 2005 to October 2014. Starting with the value of around 72%, the total return spillover plot fluctuated from 82% (from third quarter 2008 to first and second quarters 2009) to 58% (second quarter 2013). There are significant decreases in total return spillovers from 2012 to 2013 and during 2014. Total volatility spillovers follow a similar trend but the values of volatility spillover is lower than return spillover during the full-sample period, confirming the difference in total spillover Indices analyzed in previous sections. Starting at a value around 59% (significantly lower than the starting point of return spillovers at 72%), total volatility spillover rises to 69% during 2009 and drops below 52% during 2013 (in the third quarter of 2013 and the end of 2014).

Fig. 3 presents volatility spillover plot for stock indices data from 2005 to 2014.

Figs. 2 and 3 graphically illustrate cyclical movements and bursts in spillovers during recent crisis episodes, such as the global financial crisis and the European debt crisis. These patterns are consistent with opinions articulated in contagion literature, which supports the position that crisis episodes impact not only on the volatility of financial markets but also impact on the transmission of volatility across them. The Credit Crunch that started in July 2007 caused a burst in total volatility spillovers from 55% to 63% at the end of 2007 (from 67% to 75% for returns spillovers). The financial panic in stock markets during the first quarter 2008 that followed pushed further total spillovers to 67% for volatility and to 79% for returns. The Lehman Brothers collapse on September 15, 2008, became a starting point for the worldwide spread of the Great Recession and raised values of total volatility spillovers to their maximum level, 72% (82% for return spillovers). These values remained high until the economic recovery. Consequently, total spillovers began to decrease from the beginning of 2010 and by the middle of 2011 had reached their pre-crisis values. However, the plot of intra-region volatility spillovers across the Eurozone shows that there was no decline in spillovers from the beginning of 2010 as evidenced in the global trend. This difference in patterns occurred because the European debt crisis, which started in October 2009 in Greece, spread to several Eurozone state members, causing an increase in spillovers.[8]

Fig. 4 graphically illustrates volatility spillovers across the Eurozone for the period from 2005 to 2014.

[8] For the detailed timeline of European Debt Crisis see Mead and Blight (2014).

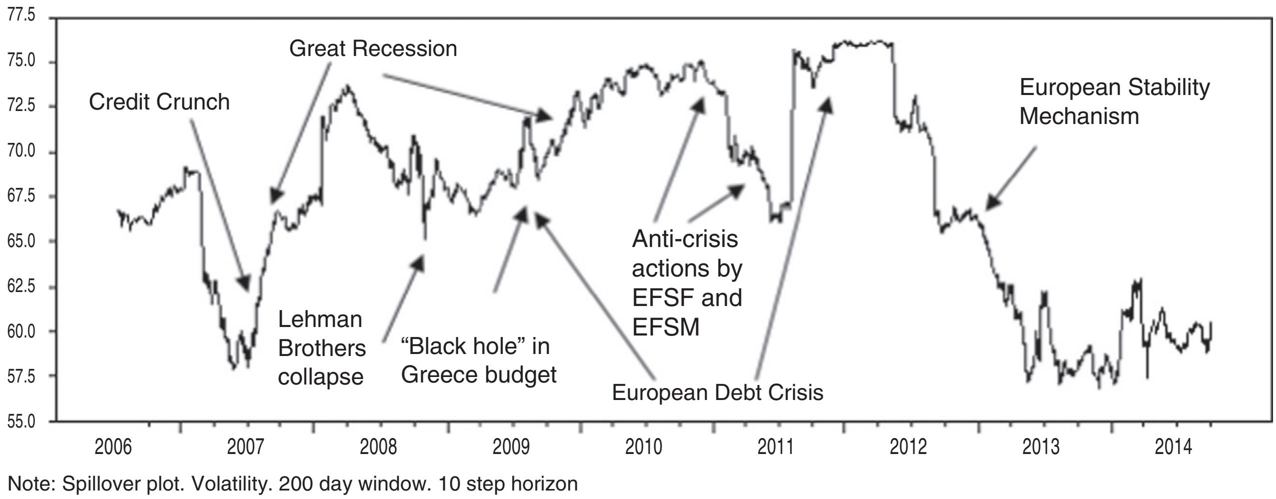

Fig. 4. Volatility spillover plot, Eurozone, stock indices, full sample.

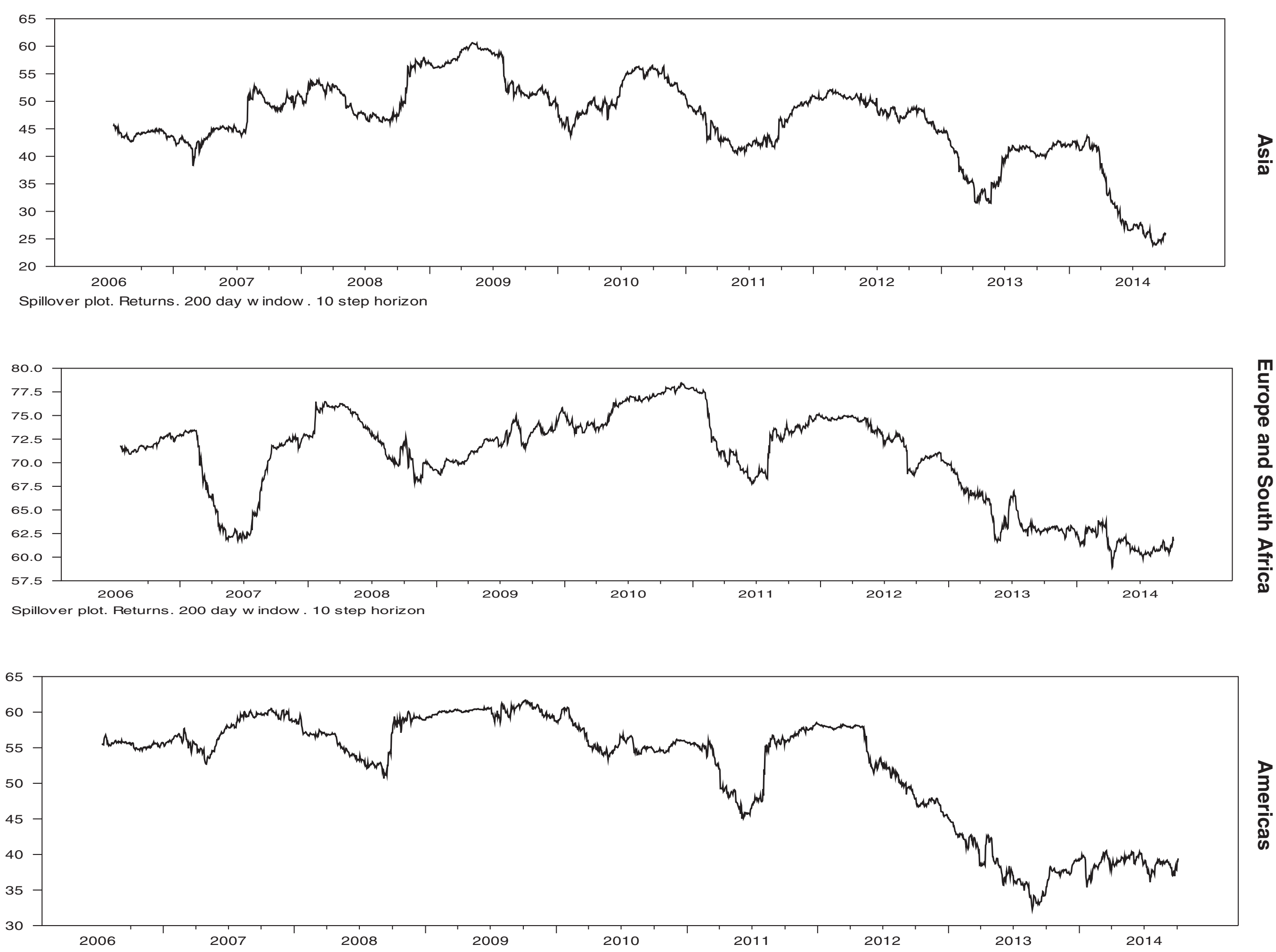

Fig. 5. Intra-regional return spillovers plot.

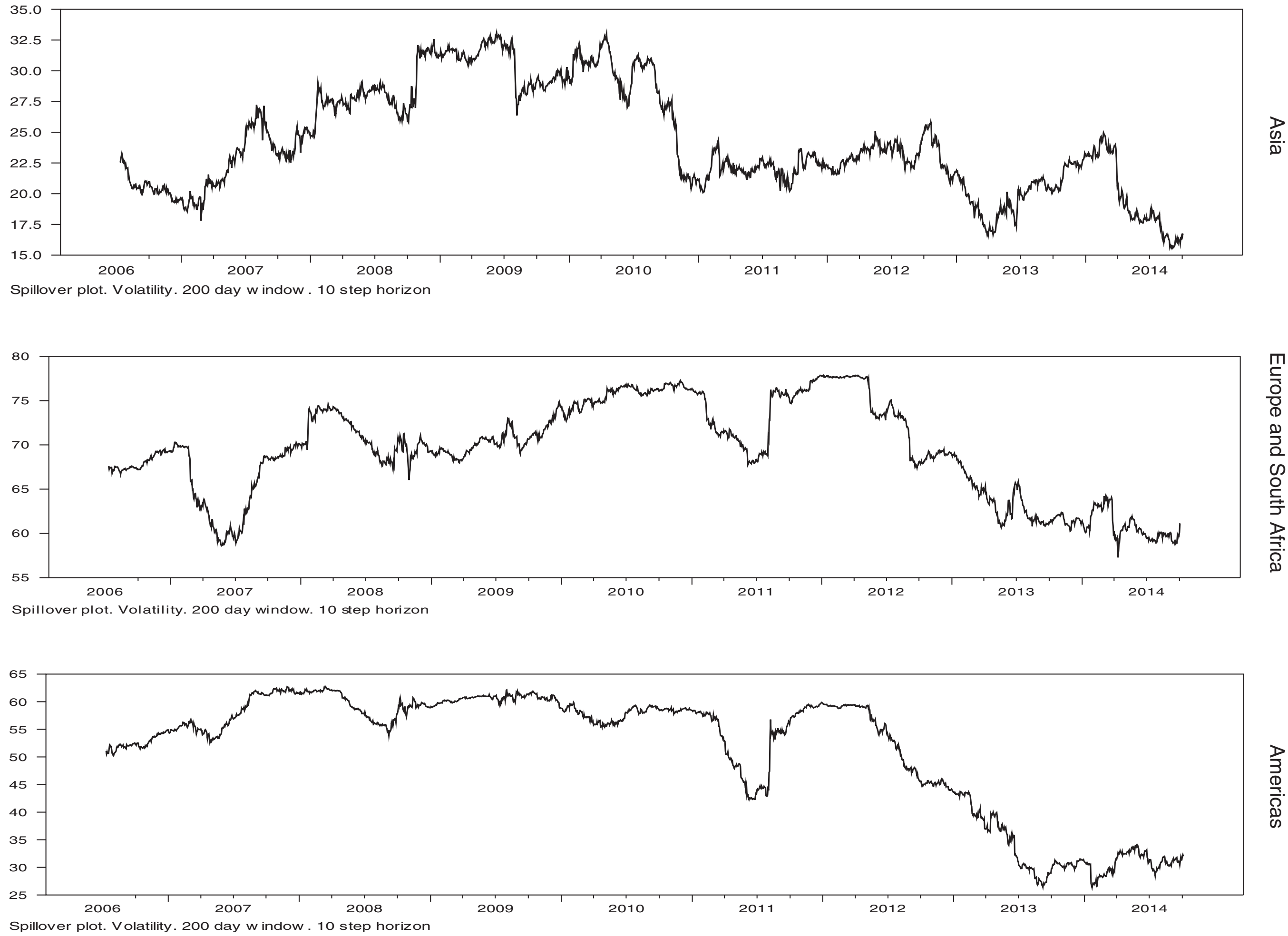

Fig. 6. Intra-regional volatility spillovers plot.

The spread of the crisis throughout the Eurozone in 2010 caused further increases in spillovers. Actions by Eurozone leaders to stabilize the situation through the European Financial Stability Facility (EFSF) and the European Financial Stabilization Mechanism (EFSM), for example the bailouts of Ireland and Portugal, initiated the recovery from the crisis. In September 2011, the IMF announced that the global economy had entered a "dangerous new phase" of sharply lower growth[9] as a result of the European debt crisis. Figs. 5 and 6 plot intra-regional return and volatility spillovers for the full-sample period for all regions separately. The highest magnitude of total spillovers is found still in the Eurozone, and total spillovers in the Americas follow the same trend as in Europe and Africa. A different situation pertains in the Asian region, where the magnitude of total intra-region spillovers across Asian countries is much lower than in the Americas and Europe for both returns and volatility. As indicated previously, Asian countries are more isolated from external shocks, and Figs. 5 and 6 confirm these findings.

5. Conclusions and recommendations for future research

This paper provides a new insight into global financial interconnectedness through the analysis of intra- and inter-regional return and volatility transmission across 21 developed and emerging markets from Asia, the Americas, Europe, and Africa. It also contributes to the discussion about the applicability of different types of data in analyses of financial dependencies of markets by documenting the evidence from both stock index futures and stock indices. The results demonstrate that futures markets provide more efficient channels of inter-regional information transmission than stock markets because the magnitude of return and volatility spillovers is larger using stock index futures data. We suggest that the analysis of spillovers across stock index futures has important practical implications for the development of trading strategies. Therefore, our findings are particularly relevant not only to academics, but also to a broad range of practitioners.

The results presented in this study have implications for asset allocation strategies and international portfolio diversification. Our findings show that Asian markets are less susceptible to external shocks and can provide better opportunities for international portfolio diversification. The research presented in this study provides significant evidence of intra-region information transmission for both futures and spot markets, but evidence of inter-regional spillovers is more limited. The spillovers between emerging and developed markets are weaker than between developed markets, so consequently the benefits of international portfolio diversification are best achievable by investing in emerging markets in different geographical zones.

Finally, our paper contributes to contagion literature evaluating global and regional spillover trends. The burst in spillovers during crisis episodes is verified, which is important for investors as during periods of turmoil diversification benefits are limited. These findings are important for policy makers and financial regulators due to the fact that contagion during crisis episodes affect macroeconomic stability. Linkages of economic cycles with intensity of global return and volatility spillovers

[9] See for news details BBC (20 September 2011). *IMF: Global economy has entered 'dangerous new phase'*.

provide the opportunity to use the intensity of spillovers as an indicator of recession and recovery. In this research, we have identified a decrease in both return and volatility spillovers from 2012 to 2014, which can be interpreted as an indication of global economic recovery.

We suggest that an investigation of spillovers across futures markets, in case of markets sequences with non-overlapping trading hours, for the purpose of analyzing the meteor shower effects, identified by Engle et al. (1990), across stock index futures within one trading day, is a key area for future research. Furthermore, as trading hours on stock index futures differ from their underlying stock indices due to the additional electronic trading hours for futures, such analysis will help provide new evidence of inter-regional information transmission and contribute to stock market predictability literature.

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