Determinants of Return and Volatility Spillovers in the International Equity Markets

Tim Leelahaphan[a], Suthawan Prukumpai[b] and Yuthana Sethapramote*[c]

This version: February 2015

Abstract:

This paper examines the determinants of spillovers in the international equity markets. The return and volatility spillovers in major international equity markets are measured by Diebold-Yilmaz spillover index. We consider both total and directional spillover indices. The results show that the total spillover index can explain the major financial contagion events during 1991-2014. Next, we examine the determinants of spillover using the panel data regressions. We focus on both countries-specific and global factors as determinant factors. The empirical results show that commodity prices (oil and gold) and financial risk factors in both global and country levels (VIX and Ted spread) can be used as indicators for financial spillover. Interesting, empirical results highlight an importance of international trade linkage as the determinants of financial market spillovers. Equity markets are prone to receive spillover effect when the degree of openness increases. In addition, the country with large trade shared in world export markets can transmit effect of its own shock to the international financial markets.

Keyword: Spillover index, International Equity Markets, Financial Contagion, Financial Linkages, Economic Integration.

JEL Classification: G01, G15, F21, E44

[a] Economist, Maybank KimEng Securities (Thailand) Public Company Limited.
[b] Lecturer, Department of Accounting, Faculty of Business Administration, Kasetsart University.
[c] Assistant Professor, School of Development Economics, National Institute of Development Administration.
*Corresponding author. Email address: yuthanas@gmail.com, yuthana.s@nida.ac.th

1. Introduction

The spread of market turbulence from one country to the others are frequently occurred in international financial market. Since the early 1990s, there are a series of severe financial crises that spillover throughout the region or global markets, for example, the Exchange Rate Mechanism (ERM) crisis of 1992; the East Asian crisis of 1997; the Brazilian Crisis or 1999; the US subprime crisis of 2007; the Greek debt crisis of 2010. The typical pattern of financial contagion is the quick transmission of the originated-country shock to the others throughout region or the world[1]. Therefore, spillover measures provide important information for monitoring the risk of financial crisis over time. In addition, understanding determinants of spillovers in international financial markets could provide crucial information for explaining contagion mechanism.

To measure degree of financial market spillover, Frobes and Rigobon (2001, 2002) estimate the volatility-corrected correlation coefficients in testing the increasing in correlation (correlation breakdown) as an indicator for financial contagion. These correlation coefficients represent the co-movement between two markets and they have also been used to describe the interdependence among financial markets. Subsequently, many empirical studies apply the traditional (static) and conditional (dynamic) correlation approaches to examine spillover and contagion in financial markets for both developed (for example, Savva et al, 2009; Billio and Caporin, 2010; Min and Hwang, 2012) and emerging markets (e.g. Chiang et al, 2007; Yiu et al, 2010; Syllignakis and Kouretas, 2011; Hwang et al, 2013). Recently, Shinagawa (2014) uses the dynamic correlation to investigate determinants of financial market spillover. Interestingly, He finds that the amount of portfolio exposure in another countries and the degree of home bias are the main factors that determined the financial market spillover.

Several empirical studies apply the correlation coefficients to investigate market interdependent and typically conclude the existent of spillovers among markets. However, strong linkages between countries are not necessarily implied financial contagion. Therefore, correlations should be applied in the study of the determinants of

[1] See Claessens, Donbusch and Park, 2001; Moser, 2003; Pericoli and Sbracia, 2003 for literature survey of studies on financial contagion.

market "interdependence", not "spillovers"[2]. Recently, Diebold and Yilmaz (2009, 2012) propose the spillover index constructed from the variance decomposition of the Vector AutoRegression (VAR) models. Since then, many empirical studies apply their methodology to investigate the spillovers among the international financial markets (e.g. McMillan and Speight, 2010; Zhou et al, 2012) and among several asset classes (e.g. Cronin, 2014). Those empirical results provide supportive evidence for the application of Diebold-Yilmaz indices in explains timing and magnitude of financial contagion in the international financial markets.

Therefore, in this paper, we apply the Diebold-Yilmaz's methodology, the spillover index in particular, to measure spillovers in the international equity markets. Furthermore, we focus on investigating the determinants of return and volatility spillovers using both countries-specific and global factors. Specifically, the financial linkage, trade integration and characteristic of country are considered as a specific factor, while the global factors represent risk condition and the strength of international equity market during a particular period of time. To represent the international equity market, nineteen equity markets are examined[3]. Our results highlight the important indicators of spillovers in the international equity markets and could provide early warning signals of financial contagion.

The rest of this paper is outlined as follows. Section 2 details the econometrics methodology for Diebold-Yilmaz's spillover index construction. The empirical results of return and volatility spillovers across international equity markets are also provided in this section. Section 3 outlines the panel regression used in estimating the determinants of spillovers. All countries-specific and global factors used as explanatory variables and empirical findings are presented in this section. Lastly, section 4 concludes and discusses the policy implication.

[2] See Forbes and Rigobon, 2002; Corsetti, Pericoli and Sbracia, 2005 for discussion on difference between the financial contagion and market interdependence.

[3] The nineteen equity markets include the US, UK, France, Germany , Hong Kong, Japan, Australia, Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, Argentina, Brazil, Chile, Mexico and Turkey. The coverage is similar to that of Diebold and Yilmaz (2009).

2. Measuring return and volatility spillovers in equity market

2.1 Methodology

Diebold and Yilmaz (2009) proposed a quantitative measure of spillovers in financial market based on the information from Variance Decomposition (VD) of forecast error associated with the *N*-variables Vector AutoRegressive (VAR) model. This approach measures spillover from shares of each cross-variable error variance in total variance forecast. The total spillover index across the *N*-variables is then computed from aggregated contributions into a single measure.

Diebold and Yilmaz (2009) used Cholesky factorization for calculating variance decomposition. Unfortunately, the results under such method, the VD based on the Cholesky decomposition, depend on the ordering of the variables. Specifically, an incorrect Cholesky ordering could mislead to results of spillover. Therefore, Diebold and Yilmaz (2012) extend the total spillover index by applying the generalized VAR framework of Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998) (KPPS, henceforth) which are invariant to the order of the variables. Moreover, Diebold and Yilmaz (2012) also propose the directional spillover, net spillover and net pairwise spillover indices to provide additional information of spillover patterns across markets. The econometric methodology of Diebold and Yilmaz (2009, 2012) can be summarized as follows.

Consider the simple case of the standard the *p*-lag *N*-variable stationary VAR model,

$$X_t = \Phi_1 X_{t-1} + \cdots + \Phi_p X_{t-p} + Bc + \varepsilon_t \quad (1)$$

where $X_t = \{X_{1,t}, X_{2,t}, \dots, X_{N,t}\}$ is a matrix of endogenous variables, c is a matrix of deterministic term (e.g. intercept term). ε_t is a vector of disturbance terms i.e. $\varepsilon_t \sim (0, \sum)$. Σ is a variance matrix of error terms that are assumed to have contemporaneous correlation with each other but are independent distributed over time.

When the variances in VAR system are covariance stationary, the moving average representation of the VAR exists and is then given by

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

where A_i is the N x N coefficient matrix; $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} \ldots + \Phi_p A_{i-p}$.

The VDs ($\theta_{i,j}(H)$) represent the contribution of a one-standard deviation shock of X_j to the variance of the H-step ahead forecast error of X_i. Based on the generalized framework of KPPS, the H-step ahead forecast error variance decomposition is

$$\theta_{i,j}(H) = \frac{\sigma_{jj} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_i)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)} \quad (3)$$

where e_i is an $Nx1$ vector with one at i element and zeros elsewhere. σ_{jj} is the standard deviation of the error term for the j^{th} equation.

The key difference of the VDs computed from the generalized method of KPPS and that of Chaloski factorization is that the sum of the contribution to the variance of the forecast error in the KPPS method is not necessarily equal to one. Therefore, Diebold and Yilmaz (2012) suggest normalizing the VD by the row sum as follow,

$$\tilde{\theta}_{i,j}(H) = \frac{\theta_{i,j}(H}{\sum_{j=1}^{N} \theta_{i,j}(H)}. \quad (4)$$

Therefore, $\sum_{j=1}^{N} \tilde{\theta}_{i,j}(H) = 1, \; \sum_{i,j=1}^{N} \tilde{\theta}_{i,j}(H) = N.$

The total spillover index that measures the contribution of spillovers across N variables to total forecast error variances is then calculated as follow,

$$TS(H) = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\theta}_{i,j}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{i,j}(H)} \times 100 = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\theta}_{i,j}(H)}{N} \times 100. \quad (5)$$

Moreover, the directional spillovers that gauge the direction spillovers GIVEN by country i to all other countries j ($DS_{i\rightarrow\cdot}(H)$) and the amounts of spillovers RECEIVED by country i from all other countries j ($DS_{\cdot\rightarrow i}(H)$) are obtained as follows,

$$DS_{i\rightarrow\cdot}(H) = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\theta}_{j,i}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{j,i}(H)} \times 100 = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\theta}_{j,i}(H)}{N} \times 100, \quad (6)$$

$$DS_{\cdot\rightarrow i}(H) = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\theta}_{i,j}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{i,j}(H)} \times 100 = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\theta}_{i,j}(H)}{N} \times 100. \quad (7)$$

Specifically, the directional spillover indices separate the total spillover into those coming from (or to) a particular source.

Diebold and Yilmaz (2012) also introduce the net spillovers and net pairwise spillovers indices. However, our paper will focus on the total spillovers as the indicators of global financial conditions and the directional spillovers for investigating the determinants of spillovers in both directions.

2.2 Empirical estimation

In this section, the return and volatility spillover indices are estimated. Not only the (unconditional) full sample periods are examined but also the (conditional) rolling sub-sample windows are investigated. To represent the international markets, we consider nineteen equity markets as presented in Table 1. Using the sample period from January 1990 to December 2014, the daily closed price indices are collected from the Datastream.

Table 1. List of International Equity Markets

Country	Abbreviation	Equity market index
The United States	U.S.	S&P500
The United Kingdom	U.K.	Ftse 100 Index (UKX)
France	FRA	Cac 40 Index (CAC)
Germany	GER	Deutsche Boerse Ag German Stock Index Dax (DAX)
Hong Kong	HKG	Hong Kong Hang Seng Index (HIS)
Japan	JPN	Nikkei 225 Index (NKY)
Australia	AUS	Australian Stock Exchange All Ordinaries Index (AS30)
Indonesia	IDN	Jakarta Stock Exchange Composite Index (JCI)
Korea	KOR	Korea Stock Exchange Kospi Index (KOSPI)
Malaysia	MYS	KLSE composite
Philippines	PHL	Philippines Stock Exchange Ps Ei Index (PCOMP)
Singapore	SGP	MSCI – Singapore
Taiwan	TAI	Taiwan Stock Exchange Weighted Index (TWSE)
Thailand	THA	SET index
Argentina	ARG	Buenos Aires Stock Exchange Merval Index (MERVAL)
Brazil	BRA	Bovespa Index
Chile	CHL	Santiago Stock Exchange Ipsa Index (IPSA)
Mexico	MEX	Mexican Stock Exchange Mexican Bolsa Ipc Index (MEXBOL)
Turkey	TUR	Borsa Istanbul 100 (XU100)

As mentioned in Diebold and Yilmaz (2009), return and volatility spillovers could display different characteristics. Therefore, our paper will consider both return and volatility spillover among nineteen international equity markets. Firstly, the daily log returns (r) are calculated as the difference between log of today price and log of yesterday price. Then daily returns are annualized by multiply by total numbers of trading day within year. Subsequently, the volatility of equity market returns (σ^2) are estimated using conditional volatility models. Specifically, we employ the EGARCH model to generate daily conditional volatilities. Again, they are annualized by multiply by the square root of total numbers of trading day within year. The descriptive statistics are summarized in Table 2.

As can be observed in Table 2 Panel A, over the period of January 1990 to December 2014, the average annual returns in international equity markets are around zero with standard deviation between two and four. In exception, the standard deviations of Brazil's, Argentina's and Turkey's equity markets are relatively higher than others – 10.89%, 6.90% and 6.60%, respectively. Most of equity market returns exhibit negative skewness with high kurtosis. These provide evidence of non-normal distribution. Turning to volatility of equity market returns in Panel B, the developed markets have relatively low volatility than the developing or emerging ones. Particularly, Australia's equity market has the lowest volatility (12.58%) over sample period following by the United States' (15.59%) and the United Kingdom's (15.59%). Not surprisingly, Brazil's equity market ranks the highest volatility (58.16%) and subsequently by Turkey's (38.71%).

2.2.1 Total spillover index: Full sample and Rolling sub-sample periods

In order to analyze a characteristic of global stock markets' return and volatility spillover, we firstly estimate the Diebold-Yilmaz spillover indices based on the VD from VAR estimation[4] using the full sample period. Subsequently, the time variation in the spillovers is explored using the rolling window estimation. The average return and variance spillovers are shown in Tables 3 and 4, respectively.

Before discussing the meaning of the spillover index, each point in Tables 3 and 4 – the ijth – denotes the estimated contribution to the forecast error variance of country i coming from shocks in country j.

[4] We follow Diebold and Yilmaz (2012) using the VAR model with four lags. See Diebold and Yilmaz (2012) for a discussion of the number of lags in VAR and sensitivity of the number of lags in an estimation of the spillover index.

Table 2. Descriptive Statistics

Panel A. Returns of International Equity Markets

	US	UK	FRA	GER	HKG	JPN	AUS	IDN	KOR	MYS	PHL	SGP	TAI	THA	ARG	BRA	CHL	MEX	TUR
Mean	0.07	0.04	0.03	0.07	0.08	-0.03	0.05	0.10	0.03	0.04	0.07	0.03	-0.04	0.02	0.21	0.60	0.15	0.12	0.32
Med	0.07	0.00	0.00	0.11	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.13	0.03
Max	27.61	23.65	26.70	27.21	43.46	33.35	15.29	33.08	28.44	52.46	40.77	27.65	19.10	28.60	66.00	174.67	29.74	44.96	44.79
Min	-23.86	-23.35	-23.87	-22.36	-37.13	-30.52	-19.00	-32.08	-32.27	-60.87	-32.98	-24.78	-24.47	-43.82	-190.8	-174.7	-19.32	-54.83	-50.35
Std.D	2.83	2.78	3.48	3.57	4.00	3.78	2.16	3.69	4.17	3.28	3.68	3.11	4.06	4.08	6.90	10.89	2.86	4.60	6.60
Skew	-0.24	-0.13	-0.03	-0.12	0.00	-0.13	-0.37	-0.07	-0.23	0.34	0.18	-0.05	-0.25	-0.18	-2.67	0.76	0.21	-0.10	0.02
Kur	9.17	6.48	4.76	4.87	10.12	5.78	5.87	9.96	4.81	50.86	9.27	6.99	3.40	8.74	97.23	113.87	6.64	12.23	4.52
Obs.	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521

Panel B. Volatilities of International Equity Markets

	US	UK	FRA	GER	HKG	JPN	AUS	IDN	KOR	MYS	PHL	SGP	TAI	THA	ARG	BRA	CHL	MEX	TUR
Mean	15.59	15.59	20.03	20.22	22.39	22.18	12.58	21.11	23.88	16.58	21.80	17.64	23.30	23.92	36.51	58.16	16.47	25.78	38.71
Med	13.66	13.83	18.42	18.19	19.45	20.89	11.67	18.62	20.77	13.54	19.96	15.55	21.09	21.66	30.58	43.66	15.05	23.06	35.49
Max	74.27	72.28	71.77	70.47	98.87	90.52	49.13	77.33	84.23	153.42	74.74	83.27	84.44	158.22	354.11	512.20	72.48	123.49	127.40
Min	5.19	6.30	9.42	8.22	9.42	8.96	5.56	5.78	8.12	4.31	9.16	5.64	8.22	9.34	13.98	17.41	5.81	10.73	13.34
Std.D	7.42	6.84	7.41	8.59	9.73	7.58	4.54	9.96	11.15	11.12	7.73	8.24	10.50	9.80	19.94	48.66	6.51	11.03	15.60
Skew	2.53	2.30	1.92	1.72	2.23	2.17	2.39	1.72	1.45	3.54	1.57	1.86	2.00	2.68	4.76	4.06	2.03	2.75	1.22
Kur	10.87	9.06	5.47	3.76	8.57	10.27	10.62	4.02	2.77	23.21	3.36	6.14	6.04	17.90	47.51	20.75	7.38	11.98	2.03
Obs.	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521	6,521

Note: The abbreviations are referred from Table 1.

As can be seen from Table 3, summing either the "contribution to others" row or the "contribution from others" column, we obtain the spillover index. It shows that 48.2% of the total 19,000 points of the total forecast error variance for all 19 countries is explained by, whereas 51.2% is explained by its own shock rather than spillover of shocks across markets. In Table 4, the volatility spillover index, 67.2%, is higher than the return spillover index, 48.2%. The difference between the two indices shows that shocks to volatility spread across the global stock markets faster than shocks to returns.

Additionally, the behavior of return and volatility spillover is examined over time by calculating the indices over rolling 200 trading-day sub-sample windows. Both return and volatility spillover indices are presented in Figure 1.

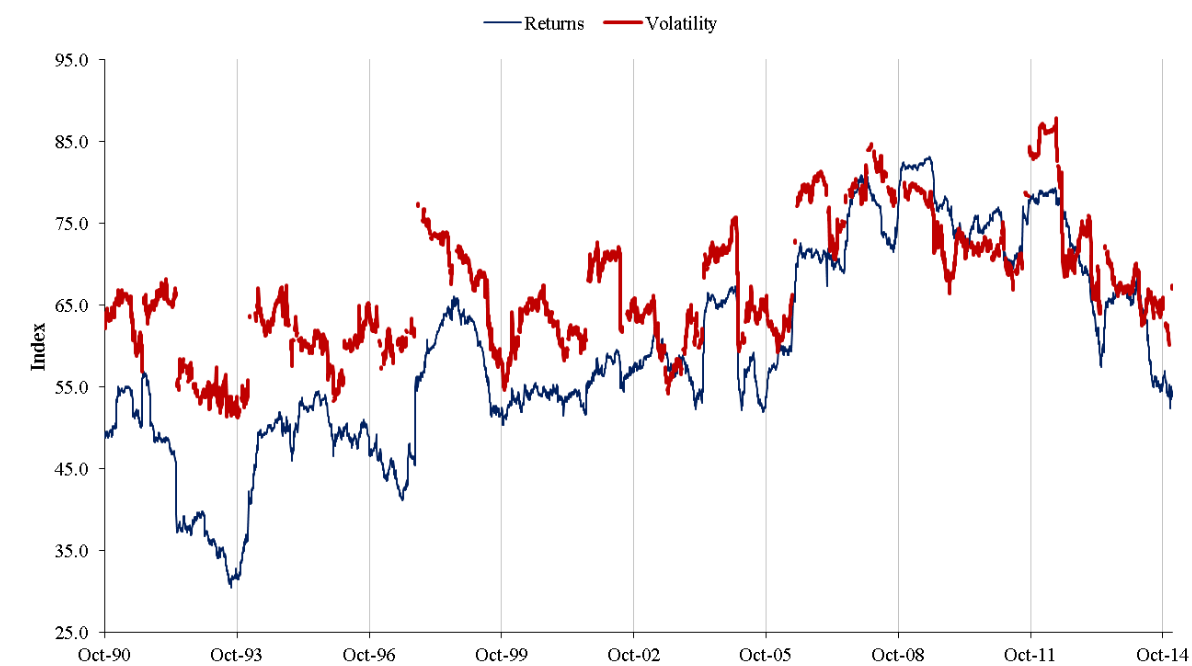


Figure 1. Spillover Plot, International Equity Market Returns and Volatility: October 1990 – December 2014. *Note:* The moving return and volatility spillover indices are estimated using rolling 200 trading-day sub-sample windows.

Clearly shown in Figure1, the spillover indices change over time and some could be explained by major global market events. Specifically, the return spillover surges from 30%

Table 3. Spillover Table, International Equity Market Returns: January 1990 – December 2014

To	From																			
	US	UK	FRA	GER	HKG	JPN	AUS	IDN	KOR	MYS	PHL	SGP	TAI	THA	ARG	BRA	CHL	MEX	TUR	Contribution from others
US	22.6	7.6	7.7	8.3	1.5	1.2	0.1	0.3	1.0	0.2	0.3	1.8	0.5	0.7	3.5	2.0	5.1	8.5	1.1	51
UK	7.0	20.6	13.3	11.0	2.4	2.0	0.1	0.8	1.3	0.6	0.3	2.4	0.5	1.2	2.1	1.1	3.6	4.8	1.5	56
FRA	6.6	13.0	20.0	13.7	2.1	1.9	0.1	0.7	1.0	0.4	0.2	2.2	0.7	1.0	2.1	1.1	3.4	4.5	1.4	56
GER	6.8	11.0	13.9	21.6	2.5	1.7	0.0	0.8	1.3	0.5	0.3	2.3	0.8	1.2	1.6	1.1	3.0	4.4	1.6	55
HKG	4.6	4.3	3.5	3.6	32.4	4.9	0.1	4.3	4.1	3.9	2.5	9.4	2.5	4.4	1.8	1.2	2.6	4.2	0.8	63
JPN	5.7	5.1	5.0	4.8	4.5	56.9	0.2	1.6	3.6	1.5	0.8	4.3	2.4	1.5	1.4	0.8	2.4	3.6	1.0	50
AUS	4.5	4.5	3.8	3.9	8.2	7.1	97.1	3.5	4.8	2.3	2.9	6.0	2.4	2.5	1.6	1.0	2.8	3.5	1.1	66
IDN	2.4	2.0	1.9	1.9	5.6	2.1	0.3	61.4	2.8	3.7	4.4	6.5	1.8	5.4	1.0	0.8	2.4	2.8	0.9	49
KOR	3.5	3.1	2.8	3.3	4.8	4.5	0.3	2.4	59.2	1.6	1.2	4.8	4.1	3.4	1.1	0.8	2.2	3.2	1.1	48
MYS	2.4	1.7	1.5	1.7	5.6	2.2	0.1	4.4	1.9	67.0	2.5	8.2	1.4	5.7	0.8	0.5	1.3	1.9	0.5	44
PHL	4.4	3.1	2.8	2.8	3.8	1.3	0.1	4.2	1.6	2.8	74.0	4.2	1.4	4.1	1.9	1.5	2.8	3.9	0.8	47
SGP	3.9	3.4	3.2	3.4	10.3	4.6	0.1	5.6	4.2	6.6	3.0	29.5	2.9	5.8	1.4	0.9	2.1	3.2	1.1	66
TAI	2.8	1.9	2.2	2.6	3.9	4.0	0.4	2.1	4.7	1.9	1.6	4.5	73.9	2.3	0.9	0.4	1.7	2.1	1.4	41
THA	2.2	2.2	2.0	2.3	5.7	2.1	0.4	5.1	3.7	5.5	3.5	6.9	1.8	55.4	1.2	0.8	2.0	2.3	1.5	51
ARG	3.6	2.9	3.0	2.3	0.9	0.4	0.1	0.4	0.6	0.2	0.4	1.1	0.2	0.7	63.4	3.1	5.3	5.6	0.6	31
BRA	2.3	1.5	1.6	1.6	0.8	0.3	0.0	0.2	0.4	0.2	0.6	0.7	0.1	0.4	3.6	75.5	4.1	4.1	0.5	23
CHL	4.8	4.3	4.2	3.6	1.6	0.7	0.2	0.7	1.1	0.4	0.7	1.6	0.6	1.1	4.9	3.4	44.5	7.0	1.0	42
MEX	8.1	5.4	5.3	5.2	2.0	1.1	0.1	0.6	1.3	0.5	0.6	1.9	0.5	1.2	5.0	3.3	6.9	28.4	1.2	50
TUR	2.0	2.4	2.3	2.6	1.3	1.1	0.2	1.1	1.5	0.5	0.5	1.8	1.5	1.9	0.8	0.8	1.5	1.9	80.9	26
Contribution to others	77	79	80	78	68	43	3	39	41	33	26	70	26	45	37	25	56	72	19	916
																				Spillover index
Contribution including own	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**48.2%**

Note: The variance decomposition is based on generalized VAR framework. The countries' abbreviation is shown in table 1.

Table 4. Spillover Table, International Equity Market Volatility: January 1990 – December 2014

To	From																			
	US	UK	FRA	GER	HKG	JPN	AUS	IDN	KOR	MYS	PHL	SGP	TAI	THA	ARG	BRA	CHL	MEX	TUR	Contribution from others
US	19.7	4.0	6.0	6.4	2.9	3.6	0.6	8.4	2.6	0.9	8.4	1.0	1.1	1.0	5.1	0.5	3.7	4.6	7.1	68
UK	8.1	11.1	10.0	8.9	3.8	0.9	2.4	4.6	4.1	1.5	4.6	1.6	0.2	3.0	3.3	3.0	5.1	5.7	1.0	72
FRA	7.9	10.2	18.2	14.5	2.7	3.0	2.2	4.5	2.7	0.1	5.0	1.1	0.4	4.2	5.7	0.7	1.8	2.9	0.2	70
GER	7.5	10.5	17.3	21.7	1.1	1.5	0.6	3.5	1.4	0.1	3.7	0.8	0.5	1.9	6.0	0.1	1.4	4.2	1.3	63
HKG	1.7	1.2	0.3	1.0	28.8	0.1	3.1	0.4	1.4	11.6	9.1	22.3	8.4	0.7	0.3	8.3	1.5	5.5	6.6	84
JPN	9.3	4.1	4.3	3.8	2.0	54.6	4.2	2.0	5.1	1.2	4.9	1.1	0.8	2.7	1.0	2.3	2.8	4.4	5.2	61
AUS	2.1	0.3	0.4	0.7	9.7	1.8	48.4	0.5	4.3	4.7	12.4	7.5	2.5	2.7	1.0	7.3	1.9	8.8	5.0	74
IDN	8.2	2.7	2.5	1.5	1.0	3.5	7.4	60.6	5.5	5.2	0.5	1.7	5.2	1.3	1.0	0.7	2.4	1.2	4.2	56
KOR	2.7	2.0	0.9	0.8	4.3	6.7	1.4	1.9	43.2	1.0	1.7	0.9	6.8	1.4	4.8	9.8	7.1	3.4	2.7	60
MYS	0.4	6.7	2.0	1.9	3.8	3.8	7.1	0.6	1.5	29.7	1.7	4.5	0.4	4.7	1.8	6.6	5.0	9.1	1.0	63
PHL	3.2	8.1	3.8	3.4	1.7	3.8	1.3	0.2	6.9	4.6	23.2	1.6	2.2	7.9	0.8	4.2	12.6	5.7	1.2	73
SGP	2.1	5.0	4.2	3.8	8.5	1.4	1.5	1.8	0.7	13.0	4.7	24.3	2.5	2.8	2.9	6.3	3.8	7.5	3.1	76
TAI	6.0	2.3	5.6	5.3	8.3	6.0	0.8	0.6	1.2	2.4	3.6	7.5	46.8	0.5	3.3	4.5	2.1	3.2	5.6	69
THA	0.6	7.0	6.6	4.5	2.9	1.0	0.8	0.7	1.5	2.2	2.4	5.8	2.4	47.2	8.8	0.6	6.2	2.3	6.9	63
ARG	1.6	4.0	4.8	3.4	0.6	2.5	2.4	4.0	3.8	2.5	2.4	5.2	0.9	8.0	43.1	3.9	3.9	2.0	2.1	58
BRA	5.2	1.7	1.3	2.2	6.7	0.7	6.2	1.8	2.2	3.4	5.1	5.9	17.2	2.2	1.2	26.4	4.2	4.2	1.8	73
CHL	7.0	4.2	2.7	2.4	5.2	0.9	1.6	1.8	5.5	0.7	2.8	1.9	0.8	2.1	3.5	5.5	21.5	4.3	2.5	56
MEX	3.3	6.8	4.3	5.1	4.9	0.3	6.7	0.6	2.1	12.0	3.4	3.1	0.5	3.2	3.3	6.6	5.2	13.1	1.1	73
TUR	3.4	8.0	4.8	8.8	1.2	3.9	1.3	1.2	4.4	3.2	0.4	2.2	0.4	2.3	3.1	2.5	7.7	7.7	41.3	66
Contribution to others	80	89	82	78	71	45	52	39	57	70	77	76	53	53	57	74	78	87	59	1277
																				Spillover index
Contribution including own	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**67.2%**

Note: The variance decomposition is based on generalized VAR framework. The countries’ abbreviation is shown in table 1.

to 50% while the volatility spillover rises from 55% to 65% immediately after the Mexican Tequila crisis at the end of 1994. This continues into 1995. Both spillover indices drop slightly during 1996 and start soaring in late 1997 according to the East Asian financial crisis. Unlike the volatility spillovers which fluctuate over periods, the return spillovers increase continuously since 1999. Both spillover indices reveal the largest movement to 80% in late 2007 at the first stage of U.S. subprime mortgage crisis. After hitting the highest level of 84% in March 2008, the volatility spillover index jumps up again at the beginning of 2012 corresponding to the European debt crisis. Since then, both spillover indices decline subsequently to the same level as in 2005. So far, the major economic and financial events result in a burst in volatility spillovers, whereas the return spillovers display an increasing trend. Our results are consistent to those of Diebold and Yilmaz (2009).

2.2.2 Directional spillover index

Thus far, we have discussed the total return and volatility spillover indices which discard directional information. As in the equations 6 and 7, the spillover RECEIVED from the others and the spillover GIVEN to the others are calculated, respectively. Instead of presenting all equity markets in one single figure, we classify them into four groups as follows:

Group 1, the "Europe plus U.S.", consists of the United Kingdom (U.K.), France (FRA), Germany (GER) and the United States (U.S.)

Group 2, the "Developed Asia", consists of Hong Kong (HK), Japan (JPN), South Korea (KOR), Taiwan (TW) and Australia (AUS)

Group 3, the "ASEAN 5", consists of Singapore (SGP), Thailand (THA), Malaysia (MYS), Philippines (PHL) and Indonesia (IDN)

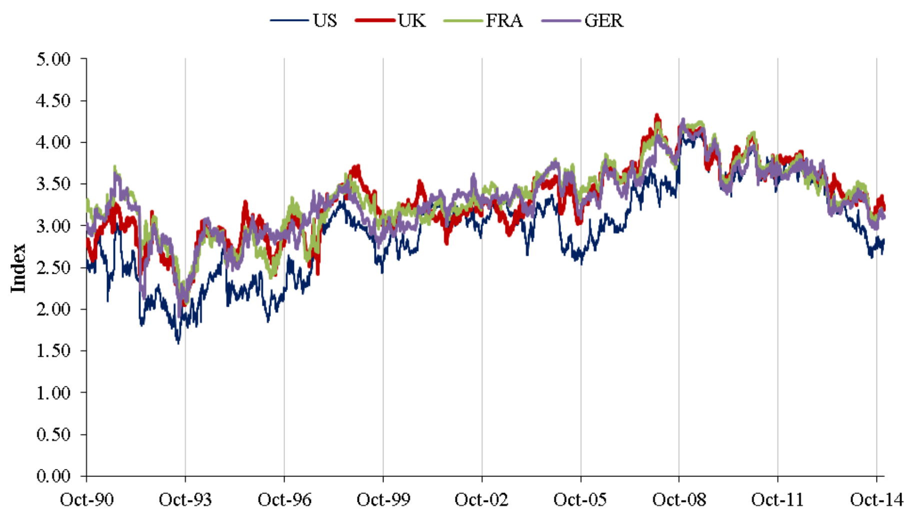
Group 4, the "Other emerging", consists of Argentina (ARG), Brazil (BRA), Chile (CHL), Mexico (MEX) and Turkey (TUR).

The return spillovers RECEIVED from the others (Ret_R) are presented in Figure 2. As can be seen, the Ret_R of Europe plus U.S. group are very similar especially among European countries and they are slightly greater than those of U.S. Overall, the indices range from 1.5% to 4% with small deviation. The Ret_R of Developed Asia group also move together especially Japan and South Korea. However, they start moving closer after 2002. Over our sample period, the indices fluctuate between 1% and 5%. Unlike the preceding, the Ret_R of ASEAN 5 and the other emerging groups exhibit diverse behavior in each country. They swing randomly with large jump e.g. Thailand and Turkey. Nevertheless, on average, the Ret_R of the other emerging group are relatively less than the others.

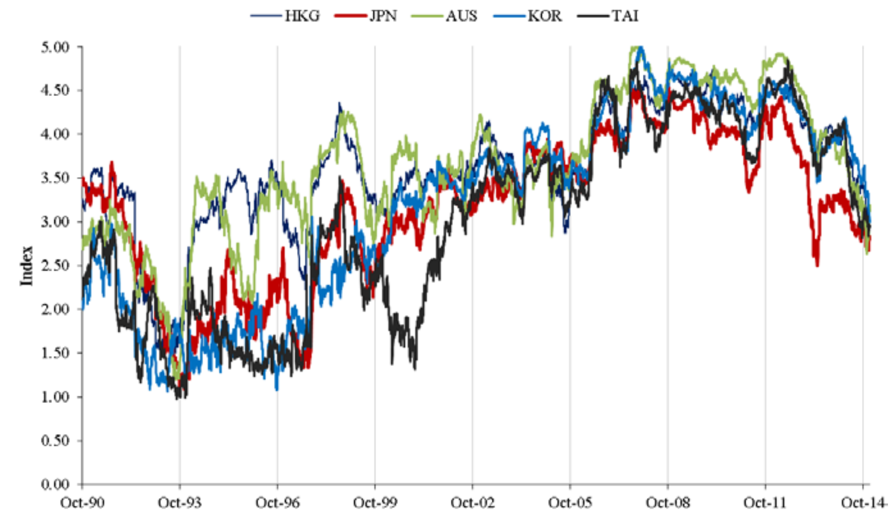
As can be observed in Figure 3, the return spillovers GIVEN to the others (Ret_G) of Europe plus U.S. group exhibit similar pattern as shown in Figure 2(a). They move together and remain stable around 4% - 4.5% since the establishment of monetary union in 1999. The other groups display different patterns. Interestingly, over time, the Ret_G of Australia are relatively lower (about 2%) and less volatile than the others while the Ret_G of Hong kong are relatively higher (about 3.5%) than the others. Again, the Ret_G of Thailand regularly bound from 1% to 4% over time. Lastly, the Ret_G of Turkey starts shifting since 2004 possibly due to the successful meeting the "60 percent EU Masstricht criterial" for public debt stock and hence was classified as a developed country by CIA. In sum, on average, the Europe plus U.S. group and Hong Kong has the highest return spillovers GIVEN to the others implied that those market fluctuations have significantly affect to the others.

Turning towards the directional volatility spillovers, Figures 4 and 5 show the volatility spillovers RECEIVED from the others (Vol_R) and the volatility spillovers GIVEN to the others (Vol_G), respectively. Not surprisingly, the Vol_R of the Europe plus U.S. group is relatively more stable than that of the others. The Vol_R is concentrated between 3% and 4% except for that of the U.S. which exhibits slightly higher volatility, in particular. The ASEAN 5 group has the highest divergence within groups; however, that of Singapore is relatively more stable. This implies that the volatility of stock market returns of ASEAN 5 is more sensitive to other shocks, compared with others.

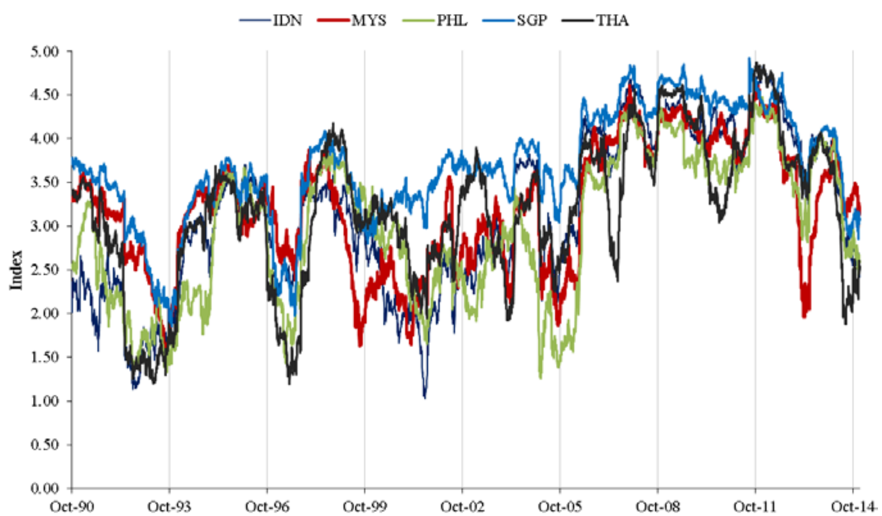
For the volatility spillovers GIVEN to the others (Vol_G), compared with others, the Europe plus U.S. group also reveals the most tightest pattern and is higher than others. Notably, the Vol_G of U.S. is relatively lower than the others within its group. Even though the Vol_G of the Developed Asia group tends to move together, it is much more fluctuating than that of the Europe plus U.S. group. Similarly, the rest two groups also exhibit large volatile patterns over a period time. Remarkably, within the ASEAN 5 group, the Vol_G of Singapore ranks the highest and consistently remains at 4%. Surprisingly, we do not find any hike in the Vol_G during the



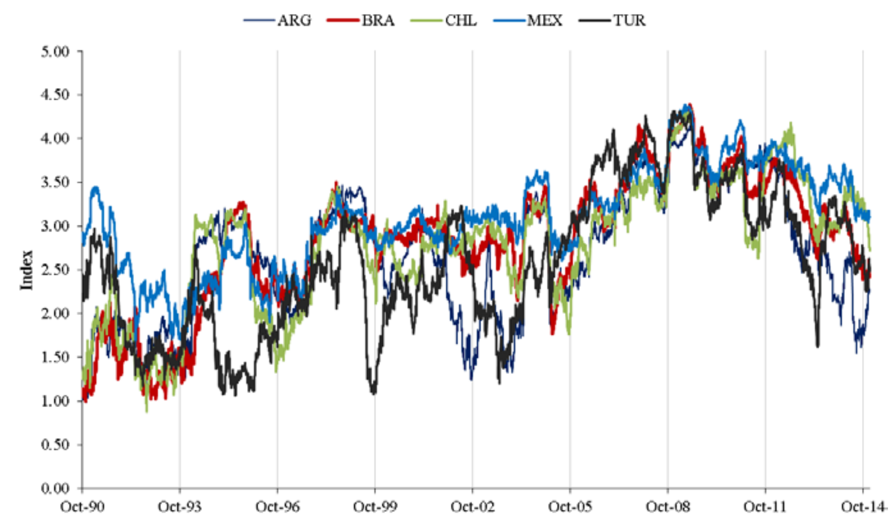
(a) Group 1 – the Europe plus U.S.



(b) Group 2 – the Developed Asia

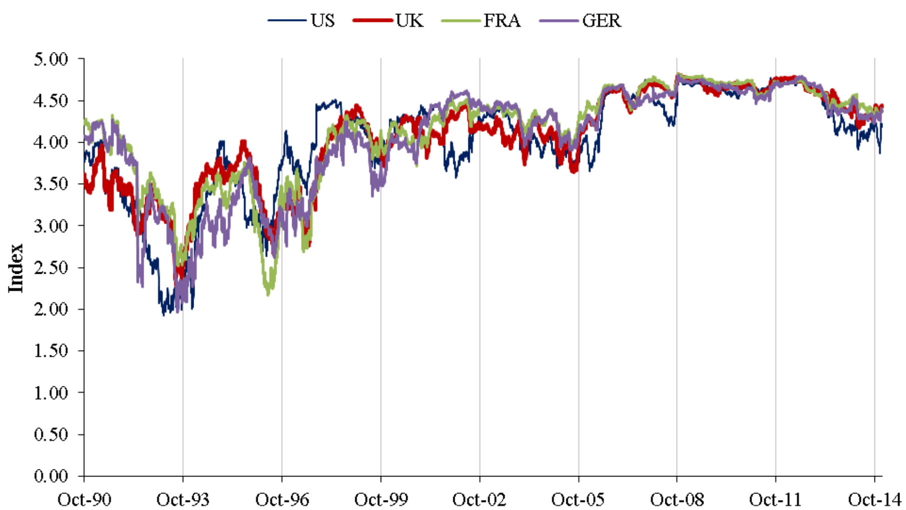


(c) Group 3 – the ASEAN 5

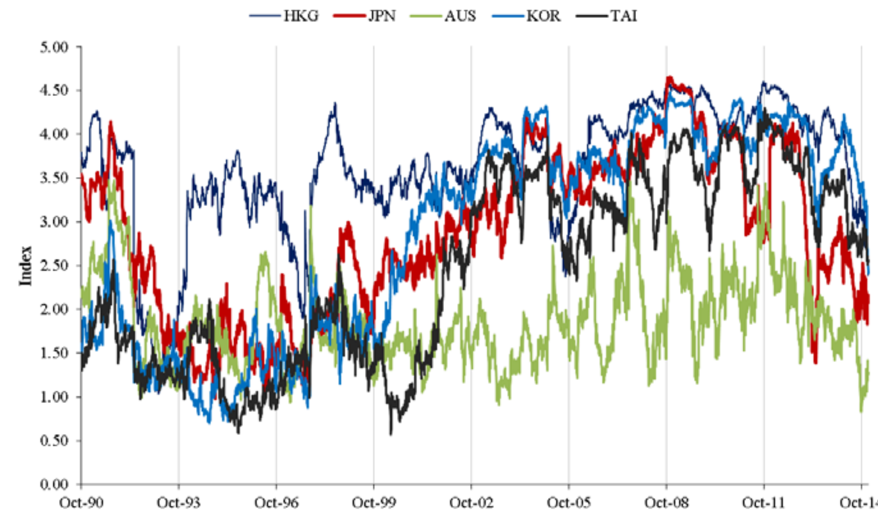


(d) Group 4 – the other emerging

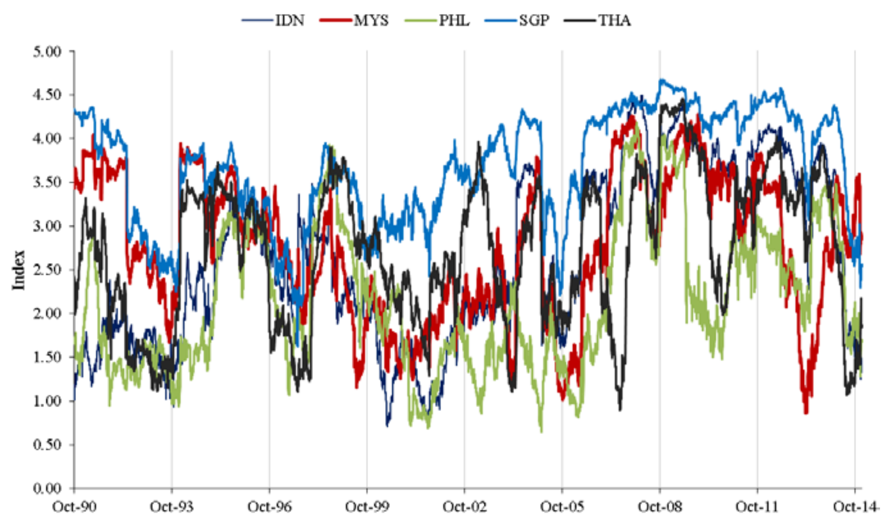
Figure 2. Directional return spillovers, RECEIVED from the others.



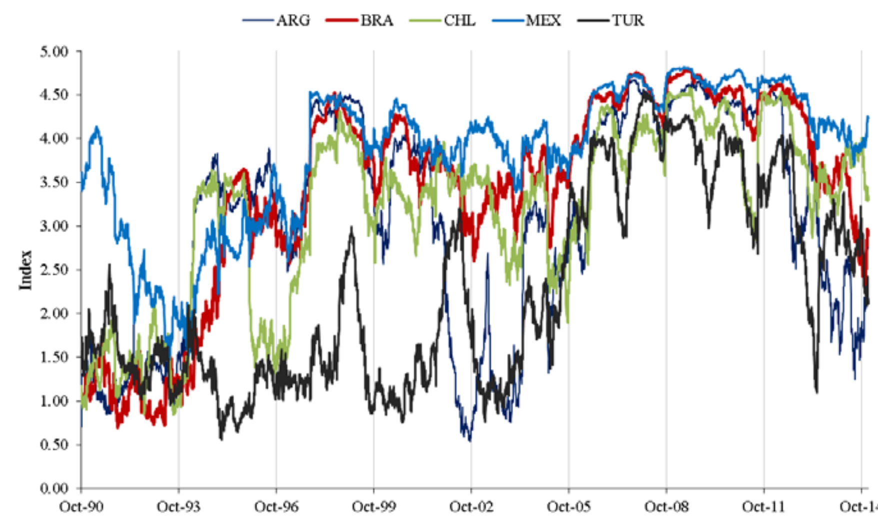
(a) Group 1 – the Europe plus U.S.



(b) Group 2 – the Developed Asia

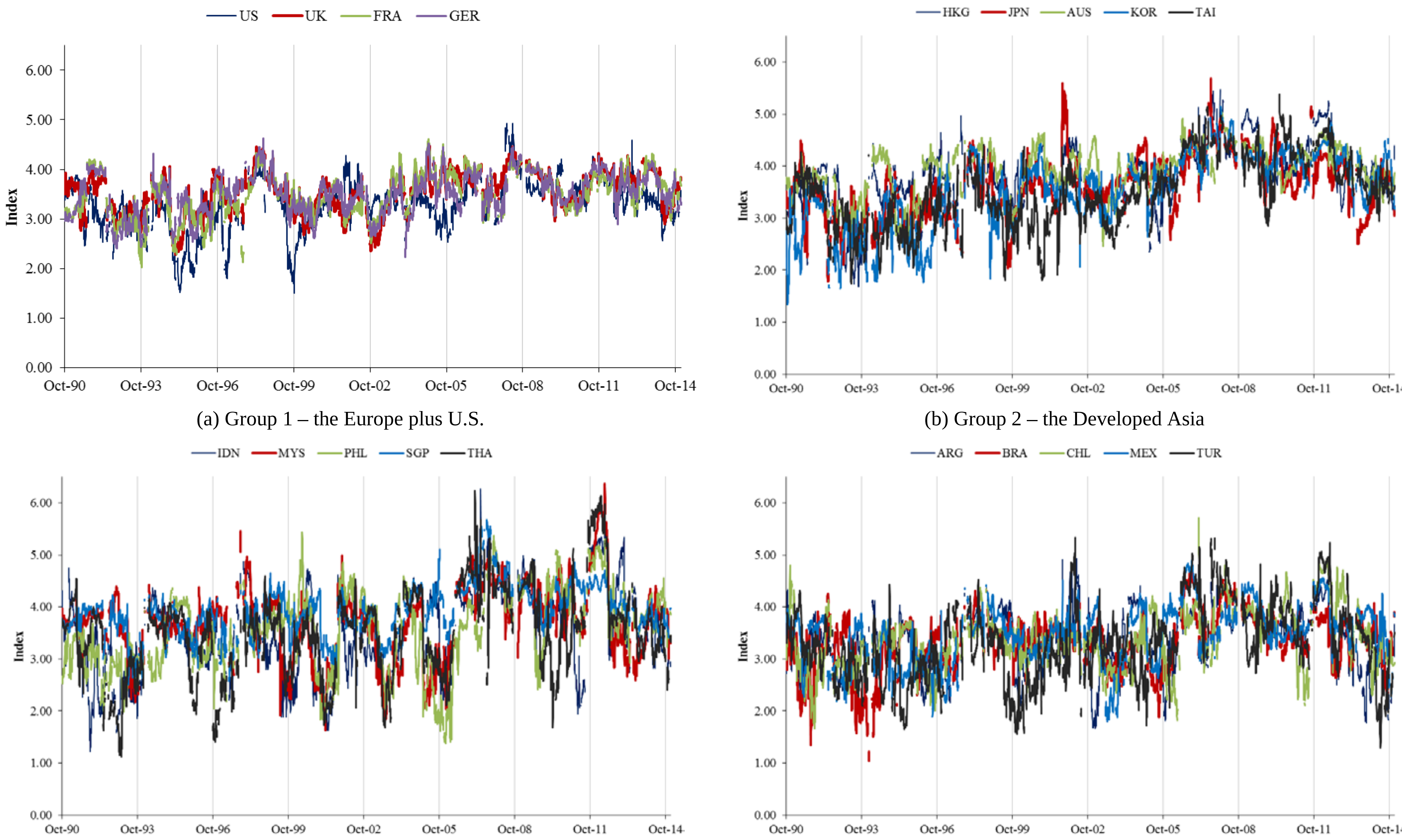


(c) Group 3 – the ASEAN 5



(d) Group 4 – the other emerging

Figure 3. Directional return spillovers, GIVEN to the others.



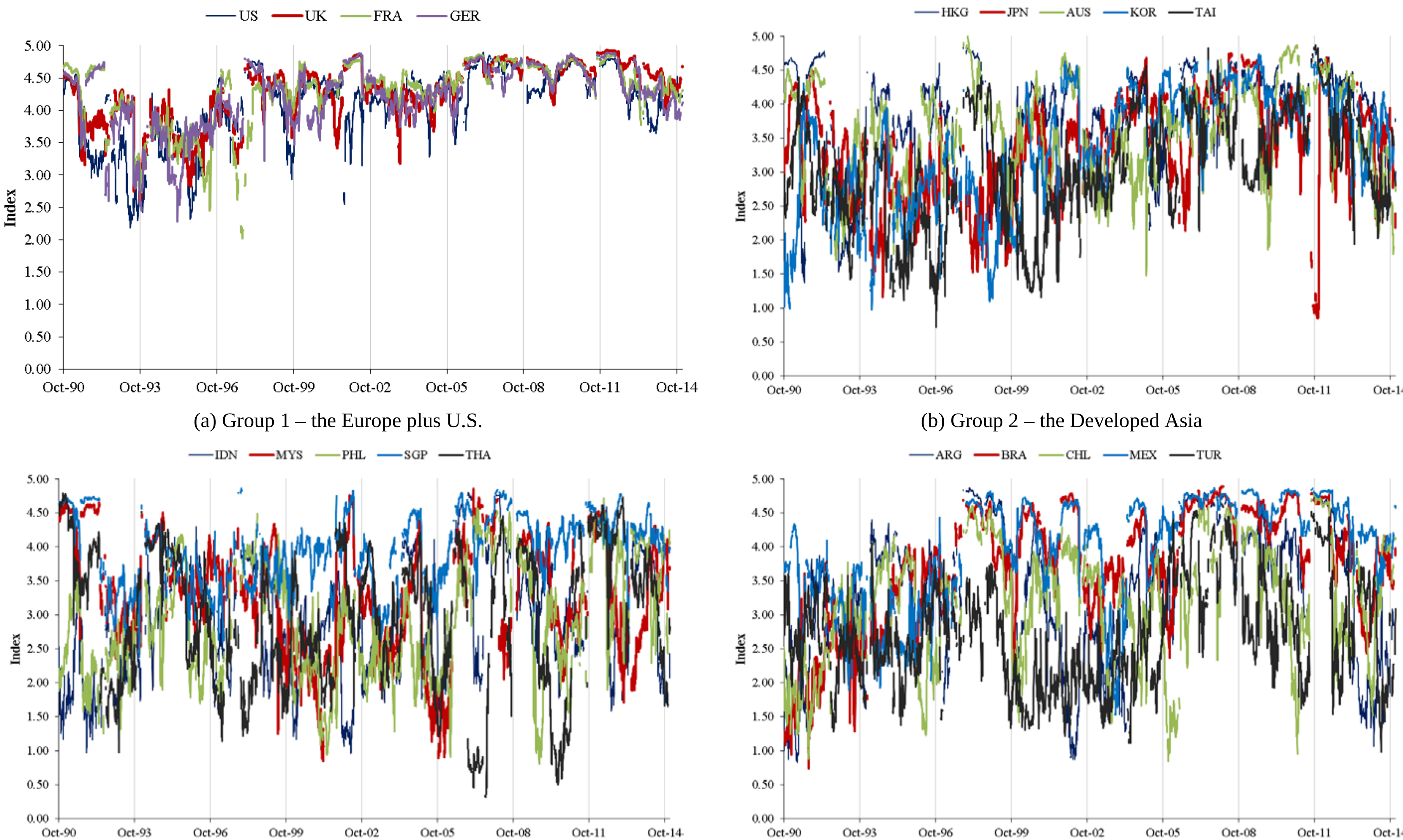
(a) Group 1 – the Europe plus U.S.

(b) Group 2 – the Developed Asia

(c) Group 3 – the ASEAN 5

(d) Group 4 – the other emerging

Figure 4. Directional volatility spillovers, RECEIVED from the others.



(a) Group 1 – the Europe plus U.S.

(b) Group 2 – the Developed Asia

(c) Group 3 – the ASEAN 5

(d) Group 4 – the other emerging

Figure 5. Directional volatility spillovers, GIVEN to the others.

1997 East Asian Financial Crisis in the ASEAN 5 group. In late 2006, the Vol_G of Thailand reaches the lowest level because of the coup d'état. The Vol_G becomes lower than 1% and then jumps to 3.5% in the mid of 2008 with the subprime crisis. Later on, the Vol_G of Thailand drops again during the second quarter of 2010 because the political protests in Bangkok.

3. Determinants of Spillovers in International Financial Markets

3.1 Spillover channels

This section, we investigated channels of the spillover in both returns and volatilities in the international equity markets. Syllignakis and Kourestas (2011) suggested that macroeconomic fundamentals had important roles in stock market correlation between central Europe countries and Germany during 2007-2009. Hwang et al. (2013) investigate the role of risk factors international financial markets. They show that sovereign CDS spread, TED spread, VIX index, foreign institutional investment and the US exchange market volatility index are important determinants of the stock market interdependences between the US and emerging economies. Later, Shinagawa (2014) found that bilateral portfolio asset holdings are the main factor that determined degree of spillovers, while the role of trade integration cannot be confirmed.

Notably, various measures of correlation coefficients are used as proxy of spillovers in those studies. Therefore, the determinants of spillovers are investigated based on the bilateral basis. In addition, the correlation coefficients are not able to specify the direction of spillovers. Hence, in this study, we examine determinants of spillovers in the international equity markets by using directional spillover indices of Diebold-Yilmaz (2012) as dependent variable. Specifically, we consider both “given” and “received” directional spillover indices computed from rolling estimation. The daily spillover indices are transformed to quarterly spillover indices by average the value of total spillover indices during given quarter. International trade and financial linkages are then used to represent the spillover channels during the financial contagion. In addition, several global risk measures are used as control variables. The details of each variable are discuss as follows:

(1) International trade linkages

International trade is usually referred to as the channel of shocks transmission from one country to the others through the real economic activities. The importance of trade linkages is not only found in business cycle synchronization but also is mentioned in the study of stock market interdependence. In this paper, we consider two measures of trade intensity: the degree of openness and the trade share in world trade. Countries with large exports and imports contribution in its output, the external shocks could provide severe impacts to the domestic real sector, in particular. Hence the financial market in those countries will prone to “receive” the spillovers from other markets. On the other hand, the countries that are regional trading center are also characterized by high degree of openness. Considering the export shares, the unexpected shocks in the countries with greater shares in world export value could potentially provide larger spillover effects to the international financial market. The international trade variables are collected from the CEIC database and they are computed as follows;

$$Open_{i,t} = (Export_{i,t} + Import_{i,t})/GDP_{i,t}$$

$$Share_{i,t} = \frac{Export_{i,t}}{Export_t^w}$$

(2) Financial risks

Financial risk factors can lead to large capital flow reversals. Specifically, losses in one market may induce investors to rebalance their portfolios by also selling in other markets. In this study, we use the countries TED spread ($TED_{i,t}$) which defined as the difference between London Interbank Offered Rate ($LIBOR_t$) and each country's short term interest rate ($i_{i,t}$); $TED_{i,t} = LIBOR_t - i_{i,t}$, and the percentage change in foreign reserves ($RES_{i,t}$) as proxy for financial risk in each country.

The short term interest rates in each country are defined as the monetary policy interest rate, discount rate or the money market rate depended on data availability in each country, while the LIBOR are based on the 3-month interbank offering rate. The data are collected from the CEIC database.

(3) Global risk factors

In this paper, we include global risk factors as control variables. Diebold and Yilmaz (2009) showed that increasing and decreasing in total spillover index could be explained by major global events. We use volatility index from the US market (*VIX_t*), gold price (*$GOLD_t$*) and crude oil price (*OIL_t*) to represent the global risk factor. These variables are collected from Bloomberg.

3.2 Empirical Estimation

In this section, the panel data regressions are used to estimate determinants of financial market spillover across market. The regressions are expressed as follows;

$$Ret_{R,i,t} = \alpha_1 + \beta_1 \mathrm{Open}_{i,t} + \gamma_1 \mathrm{Share}_{i,t} + \delta_1 \mathrm{TED}_{i,t} + \theta_1 \mathrm{RES}_{i,t} + \lambda_1 \mathrm{VIX}_t + \rho_1 \mathrm{Gold}_t + \tau_1 \mathrm{Oil}_t + u_{1,i,t}$$

$$Vol_{R,i,t} = \alpha_2 + \beta_2 \mathrm{Open}_{i,t} + \gamma_2 \mathrm{Share}_{i,t} + \delta_2 \mathrm{TED}_{i,t} + \theta_2 \mathrm{RES}_{i,t} + \lambda_2 \mathrm{VIX}_t + \rho_2 \mathrm{Gold}_t + \tau_2 \mathrm{Oil}_t + u_{2,i,t}$$

$$Ret_{G,i,t} = \alpha_3 + \beta_3 \mathrm{Open}_{i,t} + \gamma_3 \mathrm{Share}_{i,t} + \delta_3 \mathrm{TED}_{i,t} + \theta_3 \mathrm{RES}_{i,t} + \lambda_3 \mathrm{VIX}_t + \rho_3 \mathrm{Gold}_t + \tau_3 \mathrm{Oil}_t + u_{3,i,t}$$

$$Vol_{G,i,t} = \alpha_4 + \beta_4 \mathrm{Open}_{i,t} + \gamma_4 \mathrm{Share}_{i,t} + \delta_4 \mathrm{TED}_{i,t} + \theta_4 \mathrm{RES}_{i,t} + \lambda_4 \mathrm{VIX}_t + \rho_4 \mathrm{Gold}_t + \tau_4 \mathrm{Oil}_t + u_{4,i,t}.$$

The panel data consists of nineteen cross-section and time series ranging from 1991, quarter 1 to 2014, quarter 3. We estimate panel regressions using the random effect regressions. The estimation results are presented in Table 5.

The estimation results from the panel regression analysis are explained as follow. First, considering the trade intensity variables, the degree of openness are positively significant at 5% level in the ‘receive’ direction for both return and volatility spillovers. Increasing contribution of exports and imports in domestic economy, rising chance that external shocks could affect to the financial markets in both returns and volatilities. The sizes of coefficient on degree of openness variables are also similar for both return and volatility regressions. However, export shares variable displays weaker evidence. The estimated coefficients are positively significant (at 1% level) only for the return spillovers in receiving direction, in particular. For volatility regression, the export share in world market is not significant. While Shinagawa (2014) cannot find relationship between trade linkage and financial market spillover in bilateral level, our results provide the evidence supporting the role of international trade linkages to the financial spillovers using directional spillovers.

Table 5. Determinants of Equity Market Spillovers

	Ret_R		Vol_R		Ret_G		Vol_G	
OPEN	0.0976	**	0.1100	***	-0.0763		-0.0494	
	[0.0423]		[0.0308]		[0.0662]		[0.0600]	
SHARE	0.0409	***	0.0018		0.0928	***	0.0632	***
	[0.0134]		[0.0088]		[0.0219]		[0.0192]	
TED	0.0001	***	0.0001	***	0.0003	***	0.0002	***
	[3.30×10^{-5}]		[3.20×10^{-5}]		[4.36×10^{-5}]		[4.23×10^{-5}]	
RES	0.2317		0.1167		0.1852		0.0980	
	[0.1513]		[0.1471]		[0.1992]		[0.1937]	
VIX	0.0330	***	0.0183	***	0.0333	***	0.0189	***
	[0.0016]		[0.0013]		[0.0021]		[0.0021]	
GOLD	0.2533	***	0.1649	***	0.2625	***	0.1671	***
	[0.0449]		[0.0436]		[0.0592]		[0.0575]	
OIL	0.4421	***	0.1860	***	0.4705	***	0.2239	***
	[0.0374]		[0.0360]		[0.0498]		[0.0482]	
R-squared	0.5395		0.2604		0.4135		0.1747	

Notes: This is the estimation results for equity market spillovers. The first line reports estimated coefficient while the second line in parenthesis represents the standard error of coefficient. The dependent variable is the directional spillovers where Ret_R is the returns RECEIVED from others, Vol_R is the volatility RECEIVED from others, Ret_G is the returns GIVEN to others and Vol_G is the volatility GIVEN to others. The explanatory variables are as follows; OPEN denotes degree of openness, SHARE denotes export shares in world trade, TED is TED spread, RES is percentage change in foreign reserve, VIX is volatility index, GOLD is logarithm of gold price and OIL is logarithm of oil price. ***, ** and * represent significance at 1%, 5% and 10%, respectively.

For 'give' direction, we find the opposite results from those of 'receive' direction. The coefficients from degree of openness are negative but not statistically significant for both return and volatility. Nonetheless, the export share provides significant impact to both return and volatility spillovers. The spillovers spread more from countries with bigger share in world export values, while the level of openness has no significant effect in this case.

Next, we consider financial risk factor, the results exhibit strong evidence of the short term interest rate differential estimated on spillover in either directional. Both return and volatility spillover increase when TED spread widen. Conversely, the results from the foreign reserves are not significant in every case. A change in country's reserve has no significant impact on spillovers in either direction. These results show that the TED spread represent to country risk better than the foreign reserves.

Finally, all three control variables for global risks: VIX, Gold and Oil, are significantly able to explain the spillovers in every case. Moreover, magnitudes of their influence in each regression are also close to each other, for both return and volatility spillovers. These results provide indicator that a rise the VIX index, which calculated from implied volatility embedded in option prices based on S&P index, can be the indicator of financial turmoil not only for the US markets but also for all other international equity markets. An increasing in commodity prices such as oil and gold also provide alternative indicators of global instability. As can be observed in the recent crisis, e.g. Subprime crisis in the US markets, both oil and gold prices increase quickly as investors adjust their portfolio by moving from equity to commodity. The sizes of effects of world risk factor for return spillovers are higher than those of the volatilities'.

4. Conclusion

In this paper, we calculated the Spillover index based on Diebold and Yilmaz (2012)'s methodology. We consider both total and directional spillover indices. The results show that the total spillover index can explain the major financial contagion events in both 1990s and 2000s; for example Mexican Tequila crisis at the end of 1994, the East Asian financial crisis in 1997, the U.S. subprime mortgage crisis in 2007-2008 and the European debt crisis in 2011-2012.

We also examine the determinants of spillover in 'receive' and 'give' directional spillovers. Empirical results provide indicators for increasing chance of contagion in international equity markets. Firstly, our results show that increasing in spillovers can be explained by global risk factors e.g. VIX and commodity prices (gold and oil). The TED spreads also provide the indicator of spillover in individual country in every case. However, we cannot find significant relationship between foreign reserves and financial spillovers in both directions.

Secondly, our findings highlight an importance of international trade linkage as the determinants of financial market spillovers. Equity markets are prone to receive spillover effect when the degree of openness increases, in particular. In addition, the country with large trade shared in world export markets can transmit effect of its own shock to the international financial markets.

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