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# The Impact of Trade Intensity and Market Characteristics on Asymmetric Volatility, Spillovers and Asymmetric Spillovers: Evidence from the Response of International Stock Markets to US Shocks

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**Abstract**

This study examines the relationship between trade intensity and three stock market phenomena: asymmetric volatility, spillovers and asymmetric spillovers between the US and 74 international stock markets. The evidence is provided based on the cross-market models using the various measures from multivariate volatility models and the spillover indices. As stock trading gets more intensive, the market volatility responds proportionally stronger to a negative domestic shock than a positive one. Trade intensity also increases the spillovers of US shocks to the local markets. However, its impact diminishes at a higher level. Regarding other market characteristics, geographical distance, representing transaction costs or psychological /cultural obstacles, has a significant negative association with spillovers and the asymmetric spillovers. Less negative skewness, as stronger short-selling constraints, is associated with weaker spillovers. More volatile markets are generally linked to stronger asymmetries and spillovers.

Key words: asymmetric volatility; asymmetric spillovers; spillovers; trade intensity;

*JEL classification: G01, G14, G15*

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**Highlights**

- More intensively-traded stock markets respond more strongly to negative domestic shocks than positive ones, i.e. stronger asymmetric volatility, more apparent after the financial crisis.
- These markets also react to the US shocks more asymmetrically after the financial crisis, i.e. stronger asymmetric spillovers.
- They experience stronger spillovers from the US market, particularly at the stage of crisis development.
- The impact of trade intensity on spillovers diminishes at its higher level.
- Geographical distance, as a proxy for transaction costs or psychological/cultural obstacle, reduces the spillovers as well as their asymmetries. Its negative impact is much stronger at a higher quantile of spillovers.
- Less negatively-skewed market returns, as a proxy for short-selling constraints, are associated with lower spillovers.
- Market risk level increases spillovers in a lower range of spillovers but becomes irrelevant at a higher level of spillovers.

## 1. Introduction

The volatility in the stock markets responds to domestic and international shocks. Often, its responses to positive and negative shocks are different. These market phenomena of spillovers and asymmetries are well documented. The responses of volatility to domestic return shocks have been known as asymmetric (R. F. Engle & Ng, 1993). This 'asymmetric volatility' means that a negative shock to stock returns increases volatility to a greater extent than the increase by a positive shock of the same magnitude (Badshah, Frijns, Knif, & Tourani-Rad, 2016; X. Wang, Wu, & Xu, 2015) or simply a negative return-volatility relationship (Hibbert, Daigler, & Dupoyet, 2008). Black (1976) and Christie (1982) introduced the leverage effect as a cause of asymmetric volatility since a negative return shock decreases the market value of a company, increases its leverage, raises the uncertainty of the firm value and thus the volatility of returns. On the other hand, the volatility feedback hypothesis (Campbell & Hentschel, 1992; French, Schwert, & Stambaugh, 1987; Pindyck, 1984) argues that an increase in the expected volatility raises the required return on stocks and thus decreases current stock prices. Despite the fact that the leverage effect indicates a return-driven relationship and the volatility feedback implies a volatility-driven relationship between return and volatility (Jin, 2017), both agree that negative returns and larger volatility are associated with stronger asymmetric volatility. However, neither hypothesis completely explains the asymmetric volatility (Badshah et al., 2016; Hibbert et al., 2008; Wu, 2001). Also, none of the alternative behavioural explanations is universally supported either, e.g., anchoring (Ormos & Timotity, 2016), representative bias and affect heuristics (Shefrin, 2017) and disposition effects (Avramov, Chordia, & Goyal, 2006; Boujelbene, 2011; Cunha, 2015).

Most of the past studies utilise only short-term return and volatility measures to prove the existence of asymmetric volatility (Wahab, 2012; C. D. Wang & Mykland, 2014; P. Wang, Zhang, & Zhou, 2015). Additionally, they employ firm characteristics or their aggregated measures like dividend growth and its volatility (Wu, 2001) and financial leverage (Figlewski & Wang, 2001) to test a particular theory. However, the investigation of the market characteristics or economic determinants of asymmetric volatility is relatively rare since asymmetric volatility is regarded as a firm-specific or single-market phenomenon.

The reason for this missing link is that the existing studies focus little on smaller and less-insensitively traded markets such as frontier markets. For example, an abundance of studies examine the asymmetric volatility in the context of advanced (Badshah et al., 2016; Chkili, Aloui, & Nguyen, 2012; Smith, 2016) or large emerging markets such as BRIC (Christensen, Nielsen, & Zhu, 2015; Hou, 2013; Long, Tsui, & Zhang, 2014; X. Wang et al., 2015). Similarly, spillovers and their asymmetry are investigated in various developed and only some emerging markets (Abou-Zaid, 2011; Asai & Brugal, 2013; Baumöhl & Lyócsa, 2014; Beirne, Caporale, Schulze-Ghattas, & Spagnolo, 2013). This is contrary to corporate finance literature where market liquidity, size or general development is already known to affect the financing method (Demirgüç-Kunt & Maksimovic, 1996) and the growth of companies, industries and countries (Ake & Ognaligui, 2010; Arestis, Demetriades, & Luintel, 2001; Levine, 2005; Ngare, Morekwa, & Misati, 2014; Rajan & Zingales, 1998). Also, many studies of the international diversification literature focus on the frontier markets to utilise their low correlation to the global or advanced stock markets (Abdalla, 2012; Baumöhl & Lyócsa, 2014; Berger, Pukthuanthong, & Jimmy Yang, 2011; Bley & Saad, 2012; Kiviaho, Nikkinen, Piljak, & Rothovius, 2014; Samarakoon, 2011).

However, since Brooks (2007) and Jayasuriya, Shambora, & Rossiter (2009) first described that the degree of asymmetric volatility varies widely across stock markets, Talpsepp & Rieger (2010) presented evidence that the estimated parameters of asymmetric volatility from univariate volatility models have a positive relationship with GDP per capita or market capitalisation in a simple regression model. Also, recently, Bekiros, Jlassi, Naoui, & Uddin (2017) show that developed markets have stronger asymmetric volatility than emerging markets albeit they suggest social, cultural and behavioural causes without further empirical analysis. Therefore, this potential relationship now requires more formal investigation.

On the other hand, a return shock to one market can be transmitted to other markets and affect the volatility level of those recipient markets. This phenomenon is called ‘spillovers’, or specifically shock spillovers (Baruník, Kočenda, & Vácha, 2016) where volatility spillovers refer to the transmission of volatility itself. For example, evidence of spillovers from the US to Australia and China has been recently found (Allen, Mcaleer, Powell, & Singh, 2017). Spillovers are also known to exist among developing markets in Europe and Asia (Li & Giles, 2015) and in Gulf countries (Hammoudeh, Yuan, & McAleer, 2009). Spillovers during times of crisis or after a historical shock to one country are sometimes defined as financial contagion (Forbes & Rigobon, 2002; Peng & Ng, 2012) in contrast to interdependence in more tranquil periods (Corsetti, Pericoli, & Sbracia, 2005). Evidence of contagion is apparent in international stock and bond markets (Gamba-Santamaria, Gomez-Gonzalez, Hurtado-Guarin, & Melo-Velandia, 2017; Kenourgios, Samitas, & Paltalidis, 2011; Pragidis, Aielli, Chionis, & Schizas, 2015) but the results could be model-dependent (Pragidis et al., 2015; Rigobon, 2016). Both spillovers and contagion can be loosely defined as the transmission of a shock from one country to another (Rigobon, 2016), so this study refers to them as spillovers for simplicity.

The causes of spillovers could be real and financial linkages that enable international circulation of information and money although a link to a behavioural bias may exist (Talpsepp & Rieger, 2010; Tsai, 2014). Spillovers are more international phenomena, and therefore the impact of economic factors is relatively commonly investigated, e.g. macroeconomic imbalances, international trade, bank lending, foreign investment, industrial production, interest spread and sovereign risk (Forbes & Chinn, 2004; Karali & Ramirez, 2014; Philippas & Siriopoulos, 2013). Many studies employ pure times-series models, e.g. multivariate conditional variance or correlation models of return (Bae & Andrew Karolyi, 1994; Karolyi, 1995).

Like asymmetric volatility, asymmetry may also exist in spillovers (Baruník et al., 2016; Li & Giles, 2015), known as 'asymmetric spillovers'. That is, a negative shock to one market could increase the volatility transmission to the other international markets more than a positive shock does. Both asymmetric volatility and asymmetric spillovers can be called asymmetric dependence where a negative shock increases dependence among assets (Garcia & Tsafack, 2011). Note that this definition of the asymmetries is different from asymmetric responses to the same policy actions or structural changes across international financial markets (Philippas & Siriopoulos, 2013) or asymmetric interdependence in terms of the different magnitude of uni-directional spillovers between two markets. It is argued that the spillovers can be understated if the asymmetry is ignored (Bae, Yamada, & Ito, 2008).

The initial evidence of asymmetric spillovers is found among developed stock markets (Koutmos & Booth, 1995). Recent evidence includes the asymmetric spillovers between the US stock sectors (Baruník et al., 2016), from the US and Japanese to Asian stock markets (Li & Giles, 2015), from the developed to the developing stock markets (Beirne et al., 2013) and within the foreign exchange markets (Baruník, Kočenda, & Vácha, 2017), but no asymmetry is discovered between the Chinese and the US stock markets (Moon & Yu, 2010). The asymmetric spillovers are stronger between the same asset type (Garcia & Tsafack, 2011).

Asymmetric spillovers could be explained by the cross-border leverage effect or volatility feedback similar to asymmetric volatility, e.g., using quantitative difference between good and bad uncertainty (Segal, Shaliastovich, & Yaron, 2015). An alternative explanation includes the contagion from negative shocks being more correlated than positive shocks (Baruník et al., 2016; Tsai, 2014). The strength of this asymmetry may differ across financial crisis periods

(Baruník et al., 2016). Also, its degree is higher in the developed markets than the developing markets (Li & Giles, 2015), but it has not been further investigated.

Spillovers and asymmetric spillovers are important because of their impact on international diversification, portfolio management, option pricing and hedging strategies (Baruník et al., 2017; Garcia & Tsafack, 2011). However, how market characteristics are linked to the spillovers and the asymmetric spillovers has not been fully investigated, e.g., trade intensity, skewness and geographical distance. Comprehensive empirical studies on asymmetric volatility, spillovers and asymmetric spillovers covering a wide range of the advanced, the emerging and the frontier markets are not often conducted.

Therefore, this study aims to answer the two main questions. 1) How is the level of asymmetric volatility, spillovers and asymmetric spillovers associated with trade intensity and other market characteristics? Particularly, we focus on the responses of international stock markets to the shocks to the US stock market which is the largest and the most influential stock market. Then, we examine the impact of trade intensity and other market characteristics such as turnover, stock traded, market size, the strength of the negative performance, volatility level, transaction cost and short-selling constraint. 2) What is the general pattern of the asymmetries and the spillovers a) across international stock markets, b) over the global financial crisis and c) in the different quantiles of spillovers? For example, we investigate whether more developed markets are linked to a higher degree of asymmetries and spillovers, whether a period of crisis development or aftermath is more prone to asymmetries and spillovers and whether the relationship between market characteristics change as the markets show stronger spillovers.

The contribution of this paper is fourfold. First, it presents original evidence that trading intensity and certain market characteristics could be behind the asymmetric volatility, the spillovers and the asymmetric spillovers in the international stock markets. We employ multivariate volatility and correlation models, the spillover index (Diebold & Yilmaz, 2009, 2012), the market development index (Demirgüç-Kunt & Maksimovic, 1996) and the quantile regression models. Second, we generalise the findings in the earlier literature about the association between those three phenomena and economic or market-specific factors (Bekiros et al., 2017; Brooks, 2007; Forbes & Chinn, 2004; Jayasuriya et al., 2009; Philippas & Siriopoulos, 2013; Talpsepp & Rieger, 2010). Particularly, we suggest the utility of skewness and geographical distance as potential factors. Third, we suggest the new type of spillover index by employing historical decomposition (Burbidge & Harrison, 1985) that utilises residuals instead of forecasting errors. Fourth, this study provides a comprehensive picture of asymmetric volatility, spillovers and asymmetric spillovers across 74 international stock markets including little-studied frontier markets. The closest study is that of Beirne et al. (2013) which examines the spillovers of 41 emerging and frontier markets, but it did not investigate the asymmetries in either volatility or spillovers. The studies of asymmetric spillovers by Baruník et al. (2016) and Bae et al. (1994) cover one single market. Last, the impact of the global financial crisis on three market phenomena is revisited, particularly focusing on the changes over 2007 and 2008.

The remainder of the paper is structured as follows. Section 2 explains the methodology. Section 3 describes the sample data and their statistics. The results are presented and discussed in Section 4. Section 5 concludes.

## 2. Methodology

The empirical investigation is conducted in two parts. First, the degree of asymmetric volatility, spillovers and asymmetric spillovers is evaluated based on two types of models: 1) estimated parameters in bivariate conditional (co)variance or correlation models and 2) the spillover index built from bivariate vector autoregression models. Both types of models are estimated on a pair of the US market returns and each of the individual market returns. Then, the relationship between the degree of three market phenomena and the measures of trade intensity and market characteristics is formally examined in the cross-market regression models.

When investigating asymmetric volatility in individual markets, univariate asymmetric GARCH models such as the exponential GARCH (Nelson, 1991) and the GJR-GARCH model (Glosten, Jagannathan, & Runkle, 1993) are most commonly employed, e.g., Smith (2015, 2016), Zhang and Li (2008) and Awartani and Corradi (2005), where asymmetric power GARCH (Ding, Granger, & Engle, 1993) is also used. However, the examination of spillovers between markets requires multivariate models. For example, Allen et al. (2017), Long et al. (2014), Beirne et al. (2013), Wahab (2012), Moon and Yu (2010), Koulakiotis, Dasilas, & Papasyriopoulos (2009) Johansson and Ljungwall (2009), Luca et al. (2006), Karolyi (1995), Lin, Engle, and Ito (1994), among many others employ multivariate GARCH models to investigate the connectedness between the stock markets. A popular alternative includes Diebold and Yilmaz’s (2009, 2012) use of variance decomposition in a VAR model to build the spillover index (Baruník et al., 2016, 2017; Gamba-Santamaria et al., 2017).

This study measures asymmetric volatility, spillovers and asymmetric volatility based on two multivariate volatility models and the spillover index. The multivariate volatility models, 1) the fully-specified asymmetric BEKK (full-BEKK) and 2) the asymmetric dynamic conditional correlation (ADCC) models, are combined with the VAR(1)-EGARCH(1,1) models to measure three market phenomena together. Note that the aim of this study is not to identify the best fit or forecasting models, so we adopt the EGARCH, the BEKK and the ADCC for the following reasons. The EGARCH is known to capture most of the asymmetric volatility implied by other models (R. F. Engle & Ng, 1993). The full BEKK has the advantage of pinpointing the coefficients corresponding to directional and asymmetric spillovers. The ADCC model specifies conditional correlation between two markets and its asymmetry, i.e. asymmetric correlation, instead. We also employ Diebold and Yilmaz's (2009, 2012) spillover index based on the variance decomposition following their original measures while additionally utilising the historical decomposition (Burbidge & Harrison, 1985).

First, the BEKK model (R. F. Engle & Kroner, 1995) assumes that a shock $\epsilon_t$ follows a zero-mean process with the covariances conditional on the past information set $\Omega_{t-1}$, i.e.

$$\epsilon_t|\Omega_{t-1} \sim N(0, \boldsymbol{H_t}) \quad (1)$$

where $H_t$ is a $n \times n$ matrix of conditional covariances ($h_{ij}$) and n is the number of dependent variables. The conditional covariance matrix (H), is represented as:

$$\boldsymbol{H_t} = \boldsymbol{C_0'C_0} + \boldsymbol{A'\epsilon_{t-1}\epsilon_{t-1}'A} + \boldsymbol{G'H_{t-1}G} \quad (2)$$

where $\boldsymbol{\epsilon_{t-1}}$ is a vector of a shock, $\mathbf{C_0}$ is a triangular matrix and **A** and **G** are matrices of parameters. It overcomes the positive definiteness problem of the VECH model (Bollerslev, Engle, & Wooldridge, 1988) and does not require a parameter matrix **A** and **G** to be scalar or diagonal unlike scalar/diagonal BEKK or DCC (dynamic conditional correlation) models, and is thus beneficial for the study of spillovers. When all the elements in (2) are shown as the bivariate case of the full BEKK model (R. F. Engle & Kroner, 1995), n=2,

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}' \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \epsilon_{1,t-1}^2 & \epsilon_{1,t-1}\epsilon_{2,t-1} \\ \epsilon_{1,t-1}\epsilon_{2,t-1} & \epsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \quad (3)$$

$a_{21}$ in $h_{11}$ represents a spillover from the US market (market 2) to the recipient market (market 1). By adding an additional quadratic form (Kroner & Ng, 1998), the asymmetric full BEKK model is now specified:

$$\boldsymbol{H_t} = \boldsymbol{C_0'C_0} + \boldsymbol{A'\epsilon_{t-1}\epsilon_{t-1}'A} + \boldsymbol{G'H_{t-1}G} + \boldsymbol{D'\eta_{t-1}\eta_{t-1}'D} \quad (4)$$

where $\boldsymbol{\eta_t} = \boldsymbol{\epsilon_t} \times I_t$ is an interact dummy variable where $I_t$ is an indicator which has a value of 1 if $\varepsilon_t$<0 and 0 otherwise. **D** is a matrix of parameters defined as:

$$\boldsymbol{D} = \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \tag{5}$$

Statistically significant non-zero $d_{21}$ in $h_{11}$ represents asymmetric spillovers from the US market. The equation for $h_{11}$, the conditional variance of the recipient market returns, becomes:

$$h_{11,t} = c_{11}^2 + \left(a_{11}\epsilon_{1,t-1} + a_{21}\epsilon_{2,t-1}\right)^2 + \left(g_{11}h_{1,t-1} + g_{21}h_{2,t-1}\right)^2 + \left(d_{11}\eta_{1,t-1} + d_{21}\eta_{2,t-1}\right)^2 \tag{6}$$

The impact of a negative US shock ($\varepsilon_2$<0) differs from that of a positive shock as: $(a_{21}^2 + d_{21}^2)\epsilon_2^2$ vs. $a_{21}^2\epsilon_2^2$ for the given magnitude of $\epsilon_2^2$ if $\epsilon_1 = 0$. Therefore, the size of the estimated coefficient $|d_{21}|$ can indicate how much more of $\epsilon_2^2$ is translated into $h_{11}$ under a negative shock than a positive shock. They are comparable over different markets since the same origin market (the US) is employed in a bivariate setup. The estimated $|a_{21}|$ can now show the strength of the symmetric part of spillovers. The parameters are estimated by the MLE method (R. F. Engle & Kroner, 1995; Kroner & Ng, 1998).

Second, the ADCC model (Cappiello, Engle, & Sheppard, 2006) modifies the DCC model (R. Engle, 2002) which decomposes the conditional covariance matrix (H) in (1):

$$\boldsymbol{H_t} = \boldsymbol{D_t R_t D_t} \tag{7}$$

where $R_t$ is the correlation matrix with one on the diagonal and $D_t$ is the diagonal matrix with conditional standard deviations from the EGARCH on the diagonal. The evolution of the correlation is then governed by:

$$\begin{aligned} \boldsymbol{R_t} &= \boldsymbol{Q_t^{*-1} Q_t Q_t^{*-1}} \\ \boldsymbol{Q_t} &= (\bar{P} - b^2\bar{P}) + k^2(\epsilon_{t-1}\epsilon'_{t-1} - \bar{P}) + g^2(\eta_{t-1}\eta'_{t-1} - \bar{N}) + b^2\boldsymbol{Q_{t-1}} \end{aligned} \tag{8}$$

where b, g and k are scalars, $\bar{P} = E[\epsilon_t\epsilon'_t]$ and $\bar{N} = E[\eta_t\eta'_t]$. $Q^*$ is a diagonal matrix with the square root of the corresponding diagonal elements in Q i.e. $\sqrt{q_{ii}}$. The impact of negative and positive shocks on the correlation evolution in Q is different as $(k^2 + g^2)\epsilon_2^2$ vs. $k^2\epsilon_2^2$ in $q_{22}$ for the given magnitude of $\epsilon_2^2$ if $\epsilon_1 = 0$ and ignoring scalars. Thus, |g| can measure the strength of asymmetry in correlation across different market pairs, particularly since the standardised residuals ($\hat{\epsilon_i} = r_i/\sqrt{h_i}$) are used in estimation. As the correlation between market 1 and 2 ($\rho_{12}$) in **R** is $\rho_{12} = \sqrt{q_{11}}^{-1} q_{12} \sqrt{q_{22}}^{-1}$, the smaller |g| or the larger 1/|g| indicates that the correlation will be larger under a negative shock in the US market than a positive shock, unlike $|d_{21}|$ in the BEKK but similar to γ in the EGARCH below.

In the meantime, the presence of asymmetric volatility is tested by the negativity of the asymmetry coefficient (γ) in the EGARCH equation (Nelson, 1991).

$$ln(\sigma_{it}^2) = \omega_i + \alpha_i \left|\frac{\varepsilon_{it-1}}{\sigma_{it-1}}\right| + \gamma_i \frac{\varepsilon_{it-1}}{\sigma_{it-1}} + \beta_i ln(\sigma_{it-1}^2) \quad (9)$$

γ represents the extra effect of negative standardised shocks ($\epsilon_2/\sigma_2$) on a percentage change in conditional variances over positive shocks. Since larger negative γ shows a stronger impact of negative shocks, γ can be used as a measure of asymmetric volatility (Jayasuriya et al., 2009; Talpsepp & Rieger, 2010)

Third, the spillover index (Diebold & Yilmaz, 2009, 2012) as a measure of total spillovers from the US market is also employed. The spillover index, originally called the cross-variance shares, is measured from the variance decomposition of VAR models, without a conditional volatility model. Its measurement is based on how much the forecast errors in one market are caused by the US shocks. According to Diebold and Yilmaz (2009), one-step forecast errors ($e_{i,t+1}$) from a bivariate VAR can be decomposed into:

$$\begin{bmatrix} e_{1,t+1} \\ e_{2,t+1} \end{bmatrix} = \begin{bmatrix} r_{1,t+1} - r_{1,t+1|t} \\ r_{2,t+1} - r_{2,t+1|t} \end{bmatrix} = \begin{bmatrix} \psi_{11} & \psi_{12} \\ \psi_{21} & \psi_{22} \end{bmatrix} \begin{bmatrix} \epsilon_{1,t+1} \\ \epsilon_{2,t+1} \end{bmatrix} \quad (10)$$

where $r_{i,t+1|t}$ is the forecasted returns for t+1 conditional on the information set at time t. It can be shown that the variance of the forecast errors in forecasting the returns in non-US recipient markets, $\text{var}(e_1)$, is $\psi_{11}^2 + \psi_{12}^2$ assuming $\text{cov}(\epsilon_1, \epsilon_2) = 0$. Since the spillover from the US shocks ($\epsilon_2$) to the recipient market is represented by $\psi_{12}$, $\psi_{12}^2$ becomes part of the variance of the forecast errors caused by the spillovers of the US shocks. The value of the uni-directional spillover index for the non-US market is calculated as:

$$S_1^u = \frac{\psi_{12}^2}{\psi_{11}^2 + \psi_{12}^2} \quad (11)$$

To avoid the spillover index being only influenced by the last out-of-sample period, its average is calculated from the moving-windows of 200 observations with 10 out-of-sample observations, advancing by 10 observations. In the meantime, the net and bi-directional spillover index ($S^n$ and $S^b$) from the US to the recipient market is calculated by,

$$S_1^n = S_1 - \frac{\psi_{21}^2}{\psi_{22}^2 + \psi_{21}^2} = S_1 - S_2 \quad (12)$$

$$S_{12}^b = S_1 + S_2$$

The original spillover index (Diebold & Yilmaz, 2009) uses Cholesky decomposition that is subject to VAR ordering. As this study focuses on the spillovers from the US market to the other smaller international markets where the US returns are likely to be more independent, one ordering (US returns, local market returns) can be safely used. Note that the use of generalised decomposition (Diebold & Yilmaz, 2012) removes the dependence on ordering.

On the other hand, their index basically requires forecasting errors calculated from the VAR model built on the in-sample period. An alternative approach is to use all available information at the time of model estimation. Historical decomposition (Burbidge & Harrison, 1985) decomposes historical residuals from the VAR model, instead of forecast errors in (10), into structural residuals which can be attributed to each market return. Then, similar to the spillover index above (namely, the VD spillover index), the spillover index can be calculated from historical decomposition (the HD spillover index) using the same formulas, (11) and (12) on the accumulated structural residuals within the immediate past 10 observations. Generalised decomposition method is adopted for this index.

Finally, trade intensity and other market characteristics of the recipient markets, as potential determinants of three market phenomena, are measured. Trade intensity (IN) is defined as the strength of trading activities in the domestic stock markets. Four different measures are adopted. First, the turnover ratio of the stock market ($X_1$) signifies how actively stock investors participate in trading relative to total market size. It is measured as the total value of stock traded divided by market capitalisation. Second, the total value of stock traded as % of GDP ($X_2$) represents how intensively stock investors trade relative to their economic income. Third, the market capitalisation per GDP ($X_3$) measures the size of the stock market relative to economy size. Market capitalisation is not directly linked to trade intensity, but it is likely the outcome of past trade intensity. Last, a relative measure of trade intensity is calculated based on all three measures above. Following Demirgüç-Kunt and Levine’s (1996) market development index, the trade intensity index (IX) of a stock market i is defined as:

$$IX_i = \sum_{q=1}^{3} \frac{X_{qi} - \overline{X_q}}{\left|\overline{X_q}\right|} \tag{13}$$

where $\overline{X_q}$ is the average of the variable $X_{qi}$ of all sample markets.

Other market characteristics of the recipient markets are employed as follows. First, a negative-return interact dummy (NgR) is constructed by $\mathrm{NgR_t} = \mathrm{r_t} \times (\mathrm{Neg_t})$ where Neg=1 if $r_t<0$ and otherwise 0. It represents the strength of negative market performance within the sample period. It is expected to have a positive relationship with the degree of asymmetric volatility if the leverage effect exists and a negative relationship with spillovers and asymmetric spillovers if foreign investors are discouraged by poor market performance. Second, the standard deviation of returns (SdR) represents the risk level of the markets, calculated by $\sqrt{\sum(r_t - \bar{r})^2/(T-1)}$ where T is total observations. If the volatility feedback is present, a positive relationship between SdR and asymmetric volatility is expected. For a similar reason to NgR, a negative relationship with spillovers and asymmetric spillovers is expected since more volatile markets could affect the foreign investors' trading decisions. Third, the skewness of returns (SkR) is a measure of the asymmetry of return distribution, $(T/(T-1)(T-2))\sum((r_t - \bar{r})/s)^3$ where s is sample standard deviation. SkR can represent the tightness of financial constraints, particularly short-sale constraint, since the markets where short-selling is prohibited or not exercised are known to have significantly less negative skewness (Bris, Goetzmann, & Zhu, 2007). Theoretical and empirical links are also found between skewness and asymmetric volatility (Hong & Stein, 2003). For example, Wang and Mykland (2014) argue that skewness can be predicted by estimated asymmetric volatility. Harvey and Siddique (1999) show evidence that conditional skewness is linked to asymmetric volatility. Fourth, the logarithm of distance in kilometres (lnKm) between the US and a non-US recipient market represents 1) geographical, cultural or psychological obstacles for foreign investors and 2) transaction costs in a modern low-latency environment where the longer distance from the main servers of the stock exchanges means the stronger disadvantage in trading speed and consequently the larger cost to overcome it. Geographical distance is also widely-adopted as a negative driver in the gravity models for international trade (Anderson & van Wincoop, 2003; Prehn, Brümmer, & Glauben, 2016). We expect the relationship between geographical distance and spillovers, and possibly asymmetric spillovers, to be negative.

Finally, the cross-market models regress each of the measures of asymmetric volatility, spillover and asymmetric spillover (AVS) on trade intensity (IN) and market characteristics.

$$AVS_i = \xi_0 + \xi_1 IN_i + \xi_2 IN_i^2 + \boldsymbol{\xi}'\boldsymbol{c_{ij}} + v_i \tag{14}$$

where AVS is the degree of three market phenomena, ξ's are coefficients, ν is the error term and **c** is a vector of regressors for market characteristics. If the trade intensity is positively associated with asymmetric volatility (γ), the estimated coefficient of trade intensity ($\xi_1$) will be negative and significant. On the other hand, if there exists a positive relationship between trade intensity and spillovers or asymmetric spillovers, $\xi_1$ will be positive and significant. An identical set of regressors is used for all three market phenomena for better comparison although they may not be the best-fit model for each phenomenon. $IN^2$ captures a non-linear relationship since the impact of IN could be diminishing at a higher level, similar to the relationship between the market development index and the use of a bank loan (Demirgüç-Kunt & Maksimovic, 1996).

In addition, the quantile regression model (Koenker & Bassett, 1978) of (14) is estimated to investigate the nature of a non-linear relationship, if any. It investigates whether and how the different quantiles or conditional median of AVS is affected by trade intensity (IN) and market characteristics (**c**). The quantile regression estimators essentially minimise a weighted sum of the absolute deviation where AVS is spilt at a certain proportion $\phi$ below and (1- $\phi$) above. Three quantiles of 0.1, 0.5 and 0.9 will be used.

## 3. Data

Daily stock index data of 74 international stock markets for the period of January 2000 to July 2016 are collected for this study. They consist of all 22 advanced markets in the MSCI World Index, all 23 emerging markets in the MSCI Emerging Markets Index and 29 frontier markets from the MSCI Frontier Markets Index. Kuwait, Lebanon and WAEMU (West African Economic and Monetary Union) in the MSCI Frontier Markets Index are excluded due to incomplete data. The markets may have different starting dates (Table 1). The MSCI classification (MSCI, 2017) is based on market size, liquidity, length of trading, foreign inclusion etc. Note that these market value-weighted indices can be affected by the small number of large companies. Price data were extracted from Datastream and stock returns are calculated as percentage log returns.

Annual data of stock traded volume, turnover ratio and market capitalisation are obtained from the World Federation of Exchanges database via the World Bank. Geographical distances from the US in kilometres are calculated on Google Map. On the other hand, two sample periods are specified. One is the full sample period and the other is the post-crisis sample period after 15 September 2008 when Lehman Brothers collapsed. For the cross-market models, the additional sample period on and after 8 August 2007, the date when BNP Paribas froze three of their funds and known as the first sign of the sub-prime crisis, is adopted.

Table 1 presents a list of 74 sample markets and the descriptive statistics of their stock returns over the entire sample period. On average, the emerging and the frontier markets provided higher returns than the advanced markets while the emerging markets are most volatile. All the advanced and the emerging markets are moderately correlated with the US market, averaged around 30-40% with statistical significance. In contrast, 12 out of 29 frontier markets are not statistically correlated with the US market, which is consistent with the earlier literature (Berger et al., 2011; Kiviaho et al., 2014).

Insert Table 1 here

Table 2 summarises the four measures of trade intensity for all markets. On average, a more developed market group has a larger trading volume per economic income, a more intensive trading per share and a larger market size relative to economy size. That is, three groups by the MSCI classification corresponds well with the strength of trade intensity. Note that missing observations are not treated when calculating the averages. The post-crisis period shows the increase in trade intensity in the advanced and the emerging markets and the decrease in the frontier markets. The trade intensity index in (13) shows a similar pattern despite being a relative measure. The gap between the first two market groups and the frontier markets is enlarged over time.

Insert Table 2 here

## 4. Empirical results

Table 3 summarises the estimated parameters from the asymmetric BEKK models as the first type of measure of the market phenomena. The table shows the number and the proportion of the sample countries, which have significant parameters for asymmetric volatility, spillovers and asymmetric spillovers, in each market group. The results show that both asymmetries are positively linked to trade intensity. First, asymmetric volatility ($\gamma<0$) is almost universally observed in the advanced and the emerging markets, consistent with the findings of Huang and Zhu (2004), Long et al (2014), Christensen et al. (2015) and Smith (2016). However, many frontier markets do not show asymmetric volatility where trading intensity is much lower. Second, asymmetric spillovers from the US markets ($|d_{21}|>0$) are also less frequently observed in the frontier markets. On the other hand, the degree of spillovers ($|a_{21}|>0$), or precisely the symmetric part of the spillovers, does not share such a pattern. It may indicate only the asymmetric part is strongly associated with trade intensity.

Insert Table 3 here

The estimation results of the individual markets are presented in Table 4, now in terms of the measured strength of the asymmetries and the spillovers from the BEKK. On average, the frontier markets show a lower degree of spillovers and asymmetric spillovers than the advanced markets at least. Therefore, it can be argued that the degree of three market phenomena is linked to trade intensity. However, the proportion of significance and the average of measured values are rather descriptive, so it necessitates further formal analysis for the relationship between three market phenomena and the factors related to trade intensity and market characteristics.

Insert Table 4 here

The second type of measure is the spillover index. Figure 1 visualises the change in the average value of the uni-directional spillover index in three groups of markets as the strength of spillovers from the US. The figure clearly shows the advanced markets are most susceptible to the US shocks followed by the emerging and then the frontier markets. On average, about 22% of the variance of forecast errors in the advanced markets is caused by the US shocks, but around 10% in the emerging markets and less than 3% in the frontier markets.

This figure also confirms that the degree of spillovers vastly increased around late 2008 after the financial crisis while the initial increase started in 2007. It may reflect the stock investors' greater awareness of the affairs in the US stock markets after early signs of the crisis in 2007. This also justifies two post-crisis periods utilised in the cross-market models. On the other hand, it can be further evidence that the asymmetric spillovers grow with trade intensity. As the spillover index does not distinguish the asymmetric spillovers, if the degree of spillovers does not differ much over trade intensity as in Table 3, the asymmetric spillovers should be more responsible for the higher spillover index. The patterns of the bi-directional and the net spillover indices are not dissimilar to this.

Insert Figure 1 here

The cross-market model in (14) is then estimated to formally examine the relationship between the measures of three market phenomena, trade intensity and market characteristics. Table 5 (Panel A) shows that asymmetric volatility (negative $\gamma$) is indeed significantly and positively associated with most of the measures of trade intensity (IN). This finding formalises the suggestions by Bekiros et al. (2017) and Brooks (2007), who described that more developed markets tend to show stronger asymmetric volatility. It also generalises the study by Talpsepp and Rieger (2010) in a multivariate setup, who report market and economy size are relevant to asymmetric volatility. In addition, it is discovered that the relationship is quadratic, i.e. the positive impact of trade intensity on the asymmetric volatility diminishes as trade becomes even more intense. This positive relationship is particularly stronger in the stage of crisis development, i.e. around 2007. It could imply that investors tend to respond to negative shocks more strongly while the crisis is looming.

This positive association can be explained by several different reasons. The literature of behavioural biases suggests representative bias and affect heuristics (Shefrin, 2017), disposition effects (Shefrin & Statman, 1985), anchoring (De Bondt, 1993) and learning by trading (Locke & Mann, 2015; Seru, Shumway, & Stoffman, 2010) as potential reasons for asymmetric volatility (Boujelbene, 2011; Cunha, 2015; Hibbert et al., 2008; Ormos & Timotity, 2016). However, these biases should be strengthened as trade intensity increases to explain the positive relationship discovered between trade intensity and asymmetric volatility.

The well-known rational explanations based on the leverage effect and the volatility effect hypotheses may not able to explain this positive relationship with trade intensity fully for the same reason. Instead, a structural reason may be behind this positive relationship. For example, Hardouvelis & Theodossiou (2002) show that higher initial margin requirements reduce market volatility in bull markets and thus creates asymmetric volatility. Since higher initial margin requirements are likely to be introduced in the more developed markets e.g. to curtail the developing market bubbles, their explanation may be more consistent with our findings.

On the other hand, regarding other market characteristics tested, market volatility (SdR) is also positively related to the level of asymmetric volatility. That is, highly volatile markets react more strongly to own negative shocks, relative to positive shocks. This may support the volatility feedback hypothesis while the limited role of the strength of negative return (NgR) may cast some doubt over the validity of the leverage effect hypothesis. The association of both SdR and NgR with asymmetric volatility becomes weaker in the post-crisis periods.

The role of skewness (SkR) is often significant. For example, less negative skewness is linked to lower asymmetric volatility in the post-2008 period. This could be the result of widely-adopted short-selling constraints or related financial regulations that make investors unable to easily respond to negative shocks. This also confirms that less negative skewness is related to stronger short-selling constraints (Bris et al., 2007). In the earlier sample period, less negative skewness is actually associated with stronger asymmetric volatility. This only happens at a lower level of asymmetric volatility (Table 9). Short-selling constraints can temporarily hide negative information (Hong & Stein, 2003), which may initially increase the asymmetry. On the other hand, as expected, the distance to the US is not significant in explaining the asymmetric response of volatility to the domestic shocks.

Insert Table 5 here

Table 5 (Panel B) shows that asymmetric spillovers responding to the US shocks ($|d_{21}|$) are also positively and non-linearly associated with some trade intensity measures. This finding formalises the description by Li & Giles (2015) regarding the difference between the developed and the developing markets. Also, it indicates that trade intensity or related factors can be a cause of asymmetric spillovers that are recently found in the literature, e.g. Baruník et al. (2016) and Baruník et al. (2017). On the other hand, this link is relatively weaker than that of asymmetric volatility. This could be because asymmetric spillovers are part of spillovers, and thus similarly require domestic investors' increasing awareness of US markets or foreign investors' readiness to invest in the domestic markets. This can be seen in the significantly negative impact of geographical distance on asymmetric spillovers, particularly after the financial crisis. Instead, the asymmetric spillovers are more strongly linked to the risk level of domestic markets. In other words, highly-volatile markets tend to show a stronger asymmetric response to the US shocks, similar to asymmetric volatility. It confirms that the nature of two market phenomena is not different except that the asymmetric spillovers are affected by transaction costs or physical, psychological and cultural obstacles between two countries.

Table 6 (Panel A) shows how the symmetric part of spillovers from the BEKK ($|a_{21}|$) is affected by trade intensity and market characteristics. One notable difference is that trade intensity is strongly positively related to spillovers around 2007 when the crisis is in initial development. That is, although spillovers became stronger after the financial crisis (Figure 1 and also in Diebold & Yilmaz (2012)), the role of trade intensity in spillovers is the largest in the crisis development stage. On the other hand, the significance of market volatility and geographical distance is similar to the findings in asymmetric spillovers (Table 5 Panel B). However, they are relatively weaker and become insignificant in the post-2008 data.

Insert Table 6 here

Table 6 (Panel B) summarises the association between trade intensity and the asymmetry in the correlation between the US and the recipient markets ($|g|$ from the ADCC). The degree of association is not as strong as above possibly because the measure is about bilateral correlation rather than uni-directional spillovers. Nonetheless, it can be seen that more volatile and geographically-closer markets are subject more to this asymmetry after the financial crisis. Also, the markets with more negatively-skewed returns, i.e. weaker short-selling constraints, are linked to stronger asymmetric correlation. This link disappears in later sample periods. Note that the smaller $|g|$ indicates higher correlation under negative shocks in (8).

Table 7 presents the results of the cross-market model of the uni-directional VD spillover index (Panel A) and the uni-directional HD spillover index (Panel B). The uni-directional index only measures the effect of the US market on the recipient markets. In general, the impact of trade intensity on the spillover indices is particularly strong. There is a clearer positive and diminishing relationship. Two spillover indices share almost identical results regarding the sign and the significance of other market characteristics despite slightly lower statistical significance in Panel B. That is, the spillovers from the US markets increase as the recipient markets become more volatile and geographically-closer. It can be easily expected that stronger spillovers are linked to more volatile markets. However, the importance of geographical distance implies that it could be behind import and export data that is occasionally used in the spillover literature e.g. Forbes & Chinn (2004). On the other hand, less negatively skewed returns are associated with weaker spillovers in the full sample period, similar to the finding with asymmetric correlation above.

Insert Table 7 here

Table 8 shows the results with the bi-directional and net VD spillover indices in the cross-market model. The effect of trade intensity and other market characteristics on these indices is almost identical to those with the uni-directional spillover index. The reason could be that the spillovers from the non-US market to the US markets are not essentially strong, so the values of bi- or net spillover index are not much different from the uni-directional one.

Insert Table 8 here

One of the findings from the cross-market models is that the impact of trade intensity on the asymmetries and the spillovers seems to be non-linear. Particularly, a strong positive association diminishes as trade intensity goes up. To further analyse the nature of this non-linearity, the quantile regression is conducted on asymmetric volatility and net spillovers where the effect of trade intensity was more apparent. Table 9 presents the results with asymmetric volatility. The positive and diminishing role of trade intensity is clearer after the financial crisis, but the difference across the quantiles is minimal.

Insert Table 9 here

Table 10 shows the estimation results using the net spillovers. Trade intensity maintains a strong positive but diminishing relationship with net spillovers throughout three quantiles in general.

At a higher level of net spillovers, geographical distance as a proxy for transaction costs shows a much stronger negative impact which is not strongly shown at a lower level. That is, as the level of spillovers increases, transaction costs become a more important adverse factor. On the other hand, market volatility has a positive link to spillovers at the lower level of spillovers but becomes less significant at the higher level. In other words, for the recipient markets that are already highly susceptible to the US shocks, any change in the risk level may not matter in determining the spillovers.

Insert Table 10 here

In summary, the trade intensity of the stock markets is positively associated with all three market phenomena. As stock trading gets more intensive, in terms of the higher turnover ratio, the greater the value of stock traded per GDP, the larger the market capitalisation per GDP or the higher the trade intensity index, the volatility in such markets show more asymmetry in responding to the domestic or the US shocks. Also, they are affected more strongly by the US shocks in general. Their association is, however, diminishing at a high level of trade intensity. Regarding other market characteristics tested, geographical distance from the US, in particular, significantly reduces the spillovers and the asymmetric spillovers. It becomes more apparent when spillovers are already strong. This finding shed light on the role of geographical distance as a proxy for transaction costs or psychological/cultural obstacles to stock investors. The insignificant role of the strength of negative returns in the asymmetric volatility and the asymmetric spillovers does not support the leverage effect hypothesis. On the other hand, less negative skewness is associated with the weaker asymmetric volatility and the lower spillover indices. This may indicate that negative skewness can indeed represent short-selling constraints (Bris et al., 2007), but the link to the spillovers becomes insignificant after the financial crisis. More volatile markets generate a stronger degree of asymmetries in general while increasing the spillovers during the period of crisis development.

## 5. Conclusion

This paper examined three stock market phenomena: asymmetries in responding to positive and negative shocks with local or US origins (asymmetric volatility and asymmetric spillovers) and the spillovers of US shocks to the recipient markets. Specifically, the association of these market phenomena with four different measures of trade intensity was investigated. At the same time, the role of other market characteristics such as the strength of negative returns, the standard deviation and skewness of returns, and geographical distance, were examined.

The empirical evidence confirms that trade intensity plays an important role in developing these market phenomena. The findings in this study have important implications for investors. For example, as the stock market grows relative to economy or market size, i.e. more intensively-traded, the investors should expect that its volatility will respond to negative shocks more asymmetrically and the market will be more susceptible to the US shocks. Also, they can anticipate that geographically-remote or short-selling constrained markets will be less affected by the US shocks and less asymmetric to negative shocks. On the other hand, there remains much to be done. For example, the non-parametric measures of three market phenomena may be adopted to reduce model-dependent results. Bivariate volatility and return models can be extended. Also, a theoretical model can be built to explain how trade intensity affects the asymmetries and the spillovers.

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Table 1. Sample countries, market returns and correlation with the US stock markets

| Advanced | Mean | SD | cor | Emerging | Mean | SD | cor | Frontier | Mean | SD | cor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 0.012 | 1.038 | 0.218 | Brazil | 0.030 | 1.685 | 0.639 | Argentina | 0.043 | 2.278 | 0.449 |
| Austria | -0.001 | 1.564 | 0.417 | Chile | 0.021 | 1.003 | 0.508 | Bahrain | -0.013 | 1.042 | 0.092 |
| Belgium | 0.000 | 1.377 | 0.403 | China | 0.011 | 1.815 | 0.295 | Bangladesh | 0.048 | 1.579 | -0.047‡ |
| Canada | 0.013 | 1.199 | 0.993 | Colombia | 0.058 | 1.300 | 0.394 | Bosnia &H | -0.030 | 1.280 | -0.025‡ |
| Denmark | 0.041 | 1.435 | 0.336 | Czech Rep. | 0.018 | 1.480 | 0.362 | Botswana | -0.010 | 0.757 | -0.070‡ |
| Finland | -0.010 | 2.143 | 0.424 | Egypt | 0.043 | 1.741 | 0.124 | Bulgaria | 0.037 | 1.525 | 0.043 |
| France | -0.003 | 1.459 | 0.532 | Greece | -0.053 | 1.896 | 0.283 | Croatia | 0.021 | 1.307 | 0.165 |
| Germany | 0.002 | 1.514 | 0.535 | Hungary | 0.012 | 1.732 | 0.395 | Estonia | 0.025 | 1.427 | 0.171 |
| Hong Kong | 0.008 | 1.341 | 0.266 | India | 0.038 | 1.543 | 0.297 | Ghana | 0.033 | 1.148 | -0.033‡ |
| Ireland | -0.019 | 1.701 | 0.369 | Indonesia | 0.044 | 1.684 | 0.212 | Jamaica | 0.046 | 0.782 | -0.066 |
| Israel | -0.042 | 1.771 | 0.318 | Korea | 0.039 | 1.659 | 0.190 | Jordan | 0.020 | 1.094 | 0.036 |
| Italy | -0.017 | 1.526 | 0.489 | Malaysia | 0.016 | 0.883 | 0.626 | Kazakhstan | -0.002 | 2.515 | 0.164 |
| Japan | -0.012 | 1.413 | 0.212 | Mexico | 0.040 | 20.152 | 0.500 | Kenya | 0.012 | 1.387 | -0.037‡ |
| Netherland | -0.003 | 1.403 | 0.493 | Peru | 0.046 | 1.383 | 0.135 | Lithuania | 0.000 | 0.720 | 0.119 |
| New Zealand | 0.004 | 0.966 | 0.087 | Philippines | 0.022 | 1.386 | 0.396 | Mauritius | 0.051 | 1.010 | 0.033‡ |
| Norway | 0.005 | 1.873 | 0.469 | Poland | -0.003 | 1.524 | 0.092 | Morocco | 0.004 | 0.907 | -0.040 |
| Portugal | -0.024 | 1.244 | 0.400 | Qatar | -0.001 | 1.508 | 0.485 | Nigeria | 0.039 | 1.317 | 0.009‡ |
| Singapore | -0.001 | 1.213 | 0.291 | Russia | 0.031 | 2.280 | 0.421 | Oman | 0.019 | 0.986 | 0.159 |
| Spain | -0.007 | 1.559 | 0.474 | S. Africa | 0.039 | 1.262 | 0.259 | Pakistan | 0.037 | 1.595 | 0.113‡ |
| Sweden | 0.002 | 1.600 | 0.489 | Taiwan | -0.006 | 1.477 | 0.227 | Palestine | 0.005 | 0.687 | 0.085 |
| Switzerland | 0.001 | 1.177 | 0.457 | Thailand | 0.021 | 1.584 | 0.292 | Romania | 0.001 | 1.775 | 0.226 |
| UK | -0.002 | 1.203 | 0.533 | Turkey | 0.035 | 2.223 | 0.342 | Serbia | -0.058 | 1.788 | 0.105 |
| *Average* | 0.013 | 1.706 | 0.302 | UAE | -0.015 | 1.938 | 0.142 | Slovenia | 0.006 | 1.258 | 0.061 |
| Advanced | -0.002 | 1.442 | 0.418 | Ukraine | 0.044 | 3.733 | 0.051 | Sri Lanka | 0.042 | 1.485 | 0.040‡ |
| Emerging | 0.020 | 2.397 | 0.331 | Vietnam | 0.046 | 1.513 | 0.079 | Trinidad &T | 0.026 | 0.721 | 0.060‡ |
| Frontier | 0.018 | 1.358 | 0.072 | Zimbabwe | -0.003 | 1.230 | 0.083‡ | Tunisia | 0.036 | 0.540 | 0.070‡ |

Note: This table presents the summary statistics of market returns between January 2000 and July 2016. Mean is average percentage of log returns, SD is their standard deviation and cor is the Pearson correlation coefficients with the US stock returns. ‡ indicates that correlation is insignificant at the 5% level. Later start dates are used for the following markets due to data unavailability. Bahrain 31/05/2002, Bosnia & H 30/11/2010, Botswana 25/11/2008, Bulgaria 20/10/2000, Estonia 31/05/2002, Ghana 25/11/2008, Kazakhstan 30/11/2005, Lithuania 30/11/2010, Mauritius 31/05/2002, Nigeria 14/01/2000, Palestine 26/09/2013, Qatar 31/05/2005, Romania 30/11/2005, Serbia 30/05/2008, Slovenia 30/05/2002, UAE 31/05/2005, Vietnam 28/07/2000 and Zimbabwe 30/11/2010.

Table 2. Measures of trade intensity

| Advanced | Tovr | | Trad | | Mkcp | | Tidx | | Emerging | Tovr | | Trad | | Mkcp | | Tidx | | Frontier | Tovr | | Trad | | Mkcp | | Tidx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P | | F | P | F | P | F | P | F | P | | F | P | F | P | F | P | F | P |
| Australia | 75.2 | 75.3 | 81.1 | 70.5 | 107.6 | 96.2 | 2.2 | 1.7 | Brazil | 54.5 | 72.2 | 26.0 | 32.9 | 49.1 | 48.2 | -0.5 | 0.0 | Argentina | 8.3 | 5.1 | 1.4 | 0.5 | 15.5 | 10.6 | -2.6 | -2.7 |
| Austria | 39.3 | 45.7 | 11.3 | 10.6 | 28.3 | 25.0 | -1.5 | -1.5 | Chile | 13.8 | 15.8 | 14.7 | 17.0 | 103.3 | 106.9 | -0.9 | -0.7 | Bosnia &H | | | | | 21.3 | 14.5 | | |
| Belgium | 39.7 | 48.5 | 23.8 | 23.8 | 66.0 | 59.9 | -0.6 | -0.6 | China | 183.0 | 231.2 | 92.4 | 134.0 | 51.9 | 54.5 | 3.8 | 5.8 | Bahrain | 3.6 | 3.4 | 2.9 | 2.2 | 84.3 | 68.7 | -1.6 | -1.9 |
| Canada | 72.7 | 78.5 | 79.9 | 82.0 | 112.9 | 109.8 | 2.2 | 2.2 | Colombia | 15.4 | 13.3 | 5.3 | 6.8 | 49.0 | 52.6 | -1.9 | -1.8 | Bangladesh | 13.0 | 10.0 | 1.0 | 1.5 | 16.1 | 26.6 | -2.5 | -2.4 |
| Denmark | 56.3 | | 32.1 | | 55.8 | | -0.2 | | Czech Rep. | 65.4 | 78.9 | 11.8 | 9.4 | 20.8 | 17.4 | -1.1 | -1.0 | Botswana | | | | | 16.9 | | | |
| Finland | | | 117.7 | | 134.7 | | | | Egypt | 48.0 | 48.0 | 23.8 | 18.2 | 43.7 | 30.4 | -0.8 | -1.2 | Bulgaria | 19.0 | 7.4 | 2.4 | 1.2 | 15.2 | 15.5 | -2.3 | -2.6 |
| France | 82.8 | 78.4 | 62.8 | 49.7 | 78.0 | 69.8 | 1.4 | 0.8 | Greece | 46.5 | 54.6 | 21.0 | 12.7 | 41.2 | 23.9 | -0.9 | -1.3 | Croatia | | 6.4 | | 2.0 | | 40.0 | | -2.2 |
| Germany | 126.8 | 132.8 | 55.3 | 49.4 | 45.4 | 41.3 | 1.6 | 1.5 | Hungary | 72.6 | 77.2 | 15.2 | 12.2 | 20.8 | 15.7 | -0.9 | -0.9 | Estonia | | | 5.4 | | | | | |
| Hong Kong | 54.8 | 60.8 | 443.1 | 580.1 | 795.9 | 1015.1 | 21.1 | 27.7 | India | 75.1 | 68.8 | 48.4 | 49.5 | 76.1 | 73.2 | 0.9 | 0.7 | Ghana | 6.3 | 6.0 | 0.4 | 0.4 | 7.5 | 9.1 | -2.8 | -2.7 |
| Ireland | 13.5 | 14.9 | 6.6 | 5.3 | 51.4 | 42.1 | -1.8 | -2.0 | Indonesia | 34.9 | 33.2 | 10.8 | 12.0 | 33.6 | 40.5 | -1.5 | -1.5 | Jamaica | 3.1 | 5.1 | 1.7 | 2.0 | 43.6 | 32.1 | -2.3 | -2.4 |
| Israel | 37.7 | 41.6 | 27.2 | 28.9 | 71.9 | 72.0 | -0.5 | -0.4 | Korea | 30.8 | 30.7 | 23.0 | 19.7 | 87.9 | 80.0 | -0.5 | -0.7 | Jordan | 27.9 | 26.0 | 49.0 | 32.6 | 116.6 | 101.4 | 0.5 | -0.2 |
| Italy | 161.2 | 195.0 | 55.9 | 48.3 | 36.9 | 25.1 | 2.2 | 2.4 | Malaysia | 171.0 | 161.9 | 118.6 | 133.9 | 73.2 | 86.1 | 4.6 | 4.9 | Kazakhstan | 10.3 | 7.1 | 1.9 | 1.2 | 18.9 | 16.0 | -2.5 | -2.6 |
| Japan | 112.0 | 126.5 | 88.4 | 97.0 | 77.8 | 77.6 | 2.7 | 3.1 | Mexico | 30.8 | 30.9 | 41.9 | 40.9 | 136.9 | 135.8 | 0.7 | 0.6 | Kenya | 6.1 | 5.8 | 2.0 | 2.0 | 26.8 | 30.1 | -2.4 | -2.4 |
| Netherland | 108.6 | 100.1 | 94.3 | 64.4 | 90.5 | 76.5 | 2.9 | 1.7 | Peru | 27.3 | 26.7 | 8.1 | 9.7 | 30.5 | 37.1 | -1.8 | -1.7 | Lithuania | | | 1.6 | | | | | |
| New Zealand | 17.5 | 11.7 | 5.7 | 3.4 | 34.5 | 32.0 | -2.0 | -2.2 | Philippines | 7.5 | 5.0 | 2.7 | 2.2 | 39.1 | 46.4 | -2.2 | -2.2 | Mauritius | 5.6 | 5.4 | 2.9 | 3.5 | 54.7 | 66.2 | -2.0 | -1.9 |
| Norway | 77.8 | 76.9 | 41.0 | 35.8 | 52.2 | 49.5 | 0.4 | 0.1 | Poland | 16.6 | 17.4 | 9.3 | 12.2 | 55.2 | 72.4 | -1.6 | -1.3 | Morocco | 6.7 | 6.7 | 8.1 | 5.8 | 55.2 | 55.2 | -1.9 | -1.9 |
| Portugal | 64.5 | 64.2 | 24.1 | 19.2 | 36.2 | 30.8 | -0.6 | -0.8 | Qatar | 37.1 | 40.7 | 10.8 | 12.3 | 29.1 | 31.5 | -1.6 | -1.4 | Nigeria | 13.6 | 14.2 | 2.6 | 2.1 | 17.7 | 14.3 | -2.4 | -2.5 |
| Singapore | 52.2 | 46.3 | 105.0 | 101.1 | 210.0 | 232.0 | 3.8 | 3.8 | Russia | 47.7 | 47.7 | 30.2 | 26.8 | 40.6 | 40.6 | -0.7 | -0.8 | Oman | 17.8 | 17.3 | 7.7 | 7.4 | 42.6 | 45.0 | -1.8 | -1.8 |
| Spain | 133.8 | 111.4 | 107.6 | 80.9 | 81.3 | 74.8 | 3.6 | 2.4 | S.Africa | 27.1 | 29.4 | 57.3 | 67.1 | 211.4 | 232.4 | 2.1 | 2.6 | Pakistan | 205.5 | 74.1 | 41.4 | 7.5 | 25.2 | 17.3 | 2.5 | -1.1 |
| Sweden | 103.6 | | 96.5 | | 95.1 | | 2.9 | | Taiwan | | | | | | | | | Palestine | | | | | | | | |
| Switzerland | 1.1 | 73.2 | 134.3 | 138.3 | 216.0 | 196.8 | 3.6 | 4.8 | Thailand | 79.8 | 80.6 | 52.2 | 61.7 | 66.6 | 78.7 | 0.9 | 1.3 | Romania | 10.2 | 13.4 | 0.9 | 1.0 | 9.5 | 7.8 | -2.6 | -2.6 |
| UK | 78.2 | 146.4 | 94.4 | 99.4 | 120.8 | 65.0 | 2.8 | 3.4 | Turkey | 158.3 | 162.3 | 43.6 | 46.1 | 28.7 | 29.8 | 1.7 | 1.8 | Serbia | 12.5 | 7.4 | 2.2 | 1.2 | 28.4 | 21.0 | -2.3 | -2.5 |
| *Average* | 50.1 | 50.9 | 38.6 | 38.6 | 69.1 | 69.8 | 0.0 | 0.0 | UAE | 29.6 | 35.6 | 13.1 | 15.5 | 41.9 | 42.3 | -1.5 | -1.3 | Slovenia | 10.3 | 7.6 | 2.3 | 1.3 | 22.7 | 16.9 | -2.4 | -2.6 |
| Advanced | 71.9 | 80.4 | 81.3 | 83.6 | 118.1 | 125.9 | 2.2 | 2.5 | Ukraine | 5.9 | 5.9 | 0.7 | 0.7 | 22.2 | 22.2 | -2.5 | -2.5 | Sri Lanka | 15.6 | 15.4 | 3.3 | 3.9 | 20.9 | 25.4 | -2.3 | -2.2 |
| Emerging | 57.9 | 61.9 | 30.9 | 34.2 | 60.5 | 62.6 | -0.2 | 0.0 | Vietnam | 52.5 | 52.5 | 11.1 | 11.1 | 21.6 | 21.6 | -1.4 | -1.4 | Trinidad &T | 4.2 | | 1.8 | | 43.0 | | -2.3 | |
| Frontier | 21.5 | 14.4 | 6.5 | 4.3 | 32.0 | 30.4 | -1.9 | -2.2 | Zimbabwe | | | | | | | | | Tunisia | 14.1 | 14.1 | 2.4 | 2.4 | 22.6 | 22.6 | -2.3 | -2.3 |

Note: This table presents the measures of trade intensity. Tovr, Trad, Mkcp and Tidx are turnover ratio, the value of stock traded (% GDP), market capitalisation (% GDP), and the trade intensity index. 'Average' shows the average of the corresponding groups. F and P are full- and post-crisis samples, respectively. Ukraine, Vietnam and Zimbabwe are the frontier markets.

Table 3. Asymmetric volatility, spillovers and asymmetric spillovers from BEKK – summary

| | | F | | P | | Total |
|---|---|---|---|---|---|---|
| Asymmetric Volatility $\gamma<0$ | Advanced | 22 | 100% | 21 | 95% | 22 |
| | Emerging | 23 | 100% | 23 | 100% | 23 |
| | Frontier | 17 | 59% | 23 | 79% | 29 |
| | All | 62 | 84% | 67 | 91% | 74 |
| Spillover $\lvert a_{21}\rvert>0$ | Advanced | 14 | 64% | 13 | 59% | 22 |
| | Emerging | 16 | 70% | 15 | 65% | 23 |
| | Frontier | 19 | 66% | 17 | 59% | 29 |
| | All | 49 | 66% | 45 | 61% | 74 |
| Asymmetric Spillover $\lvert d_{21}\rvert>0$ | Advanced | 18 | 82% | 15 | 68% | 22 |
| | Emerging | 14 | 61% | 12 | 52% | 23 |
| | Frontier | 13 | 45% | 16 | 55% | 29 |
| | All | 45 | 61% | 43 | 58% | 74 |

Note: This table shows the numbers and the percentage of the countries that contain significant asymmetric volatility ($\gamma<0$), spillovers ($\lvert a_{21}\rvert>0$) or asymmetric spillovers ($\lvert d_{21}\rvert>0$) in each market group of different development. The results are from the asymmetric full-BEKK model. F and P indicate the full and the post-crisis sample periods, respectively.

Table 4. Asymmetric volatility, spillovers and asymmetric spillovers from BEKK – individual markets

| Advanced | Full | | | Post-crisis | | | Emerging | Full | | | Post-crisis | | | Frontier | Full | | | Post-crisis | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\gamma$ | $\lvert a_{21}\rvert$ | $\lvert d_{21}\rvert$ | $\gamma$ | $\lvert a_{21}\rvert$ | $\lvert d_{21}\rvert$ | | $\gamma$ | $\lvert a_{21}\rvert$ | $\lvert d_{21}\rvert$ | $\gamma$ | $\lvert a_{21}\rvert$ | $\lvert d_{21}\rvert$ | | $\gamma$ | $\lvert a_{21}\rvert$ | $\lvert d_{21}\rvert$ | $\gamma$ | $\lvert a_{21}\rvert$ | $\lvert d_{21}\rvert$ |
| Australia | -0.08* | 0.09* | 0.22* | -0.07* | 0.34* | 0.14* | Brazil | -0.06* | 0.56* | 0.07 | -0.11* | 0.02* | 0.03 | Argentina | -0.05* | 0.16* | 0.21* | -0.09* | 0.64* | 0.49* |
| Austria | -0.08* | 0.04* | 0.09* | -0.07* | 0.57 | 0.68* | Chile | -0.08* | 0.00 | 0.04* | -0.05* | 0.28 | 0.07* | Bosnia &H | -0.10* | 0.01 | 0.01 | -0.10* | 0.08 | 0.01 |
| Belgium | -0.11* | 0.38* | 0.31* | -0.08* | 0.65* | 0.30* | China | -0.03* | 0.73* | 0.23* | -0.06* | 0.52* | 0.08 | Bahrain | 0.01 | 0.17* | 0.12* | -0.12* | 0.06* | 0.11* |
| Canada | -0.08* | 1.09* | 0.25 | -0.10* | 0.30 | 2.00* | Colombia | -0.05* | 0.04* | 0.03 | -0.06* | 0.13* | 0.02 | Bangladesh | -0.09* | 0.01 | 0.01 | 0.00* | 0.01* | 0.04 |
| Denmark | -0.04* | 0.00 | 0.42* | -0.03* | 0.51 | 0.17 | Czech | -0.07* | 0.49* | 0.06 | -0.06* | 0.16* | 0.47* | Botswana | -0.03* | 0.04* | 0.09* | -0.05* | 0.26* | 0.09* |
| Finland | -0.05* | 0.08* | 0.18* | -0.06* | 0.00 | 0.08 | Egypt | -0.04* | 0.01 | 0.32* | -0.06* | 0.50* | 0.17* | Bulgaria | 0.00 | 0.02* | 0.09* | -0.06* | 0.37* | 0.07* |
| France | -0.13* | 0.42* | 0.14* | -0.10* | 0.32* | 0.16 | Greece | -0.04* | 0.02 | 0.03 | -0.05* | 0.04 | 0.27 | Croatia | -0.01* | 0.03* | 0.11* | -0.08* | 0.46 | 0.15* |
| Germany | -0.11* | 0.05* | 0.09* | -0.03* | 0.06* | 0.31* | Hungary | -0.05* | 0.28* | 0.05 | -0.04* | 0.03* | 0.06 | Estonia | 0.01* | 0.09* | 0.02 | -0.10 | 0.20* | 0.05 |
| Hong Kong | -0.05* | 0.21 | 0.45 | -0.06* | 0.26* | 0.24* | India | -0.08* | 0.12* | 0.35* | -0.12* | 0.05* | 0.32* | Ghana | -0.11* | 0.01 | 0.42* | -0.06* | 0.52 | 0.43* |
| Ireland | -0.07* | 0.08* | 0.02 | -0.02* | 0.35* | 0.06 | Indonesia | -0.06* | 0.20* | 0.17* | 0.05* | 0.18* | 0.27* | Jamaica | 0.04* | 0.02* | 0.00 | 0.12* | 0.29* | 0.01 |
| Israel | -0.03* | 0.15* | 0.04 | -0.11* | 2.33 | 0.38 | Korea | -0.04* | 0.01 | 0.12* | -0.10* | 0.57* | 0.19* | Jorden | 0.03* | 0.05* | 0.02 | -0.07* | 0.20* | 0.12* |
| Italy | -0.10* | 0.03 | 0.04* | -0.08* | 0.20* | 0.06 | Malaysia | -0.06* | 0.07* | 0.06* | 0.04* | 0.24* | 0.08* | Kazakhstan | -0.06* | 0.02 | 0.02 | -0.12* | 0.49 | 0.51* |
| Japan | -0.09* | 0.13* | 0.16* | -0.04* | 0.59* | 0.18* | Mexico | -0.92* | 0.82 | 1.08 | -0.07* | 0.67 | 0.22* | Kenya | -0.02* | 0.42* | 0.05 | -0.02 | 0.85* | 0.06* |
| Netherlands | -0.12* | 0.02 | 0.06* | -0.08* | 0.32 | 0.67* | Peru | -0.05* | 0.03 | 0.05 | 0.00* | 0.22 | 0.05 | Lithuania | -0.04* | 0.12* | 0.17* | -0.07* | 0.43* | 0.22* |
| New Zealand | -0.03* | 0.37* | 0.24* | -0.05 | 0.67* | 0.11* | Philippines | -0.04* | 0.25* | 0.24* | -0.06* | 0.52* | 0.20* | Mauritius | 0.02* | 0.11* | 0.10* | -0.02* | 0.29* | 0.01 |
| Norway | -0.08* | 0.14* | 0.14* | -0.02* | 0.18* | 0.78* | Poland | -0.04* | 0.60* | 0.04 | -0.04* | 0.06* | 0.06 | Morocco | -0.02* | 0.02 | 0.01 | -0.12* | 0.02 | 0.16* |
| Portugal | -0.08* | 0.02 | 0.07* | -0.03* | 0.39 | 0.17* | Qatar | -0.03* | 0.03* | 0.13* | -0.08* | 0.35* | 0.26* | Nigeria | 0.16* | 0.09* | 0.03 | -0.02 | 0.56* | 0.03 |
| Singapore | -0.06* | 0.09* | 0.24* | -0.08* | 0.73 | 0.27* | Russia | -0.05* | 0.03 | 0.39* | -0.01* | 0.19 | 0.70* | Oman | -0.07* | 0.04* | 0.12* | -0.10* | 0.28 | 0.13* |
| Spain | -0.11* | 0.07* | 0.07* | -0.01* | 0.46* | 0.34* | S.Africa | -0.08* | 0.19* | 0.18* | -0.07* | 0.22* | 0.25* | Pakistan | -0.07* | 0.01 | 0.02 | -0.13* | 0.49 | 0.00 |
| Sweden | -0.09* | 0.00 | 0.44* | -0.07* | 0.73 | 0.29 | Taiwan | -0.06* | 0.05* | 0.25* | -0.03* | 0.04 | 0.28 | Palestine | -0.01 | 0.01 | 0.00 | 0.02 | 0.13* | 0.05 |
| Switzerland | -0.14* | 0.04 | 0.07* | -0.15* | 0.26* | 0.21* | Thailand | -0.07* | 0.42* | 0.02 | -0.12* | 0.50 | 0.03 | Romania | 0.08* | 0.44* | 0.23* | -0.06* | 0.52* | 0.00 |
| UK | -0.12* | 0.02 | 0.09* | -0.11* | 0.19* | 0.16* | Turkey | -0.04* | 0.06* | 0.18* | -0.01* | 0.43 | 0.21 | Serbia | -0.04* | 0.15 | 0.40* | -0.07* | 0.40 | 0.21 |
| *Average* | -0.07 | 0.16 | 0.15 | -0.06 | 0.35 | 0.22 | UAE | -0.06* | 0.21* | 0.07* | 0.01* | 0.25* | 0.03 | Slovenia | -0.02* | 0.31* | 0.33* | -0.09* | 0.07 | 0.35* |
| Advanced | -0.08 | 0.16 | 0.17 | -0.07 | 0.47 | 0.35 | Ukraine | -0.29* | 0.11 | 0.47* | -0.01 | 0.29* | 0.10 | Sri Lanka | -0.01 | 0.20* | 0.04 | -0.06* | 0.06 | 0.45* |
| Emerging | -0.09 | 0.23 | 0.18 | -0.05 | 0.27 | 0.19 | Vietnam | 0.00 | 0.07* | 0.03 | -0.04* | 0.50 | 0.50 | Trinidad &T | -0.60* | 0.16* | 0.02 | -0.07* | 0.38* | 0.04* |
| Frontier | -0.05 | 0.10 | 0.11 | -0.06 | 0.32 | 0.15 | Zimbabwe | -0.05 | 0.06 | 0.01 | -0.05 | 0.06 | 0.01 | Tunisia | -0.04* | 0.06* | 0.01 | -0.12* | 0.39* | 0.02* |

Note: This table shows the estimates from asymmetric BEKK models. $\gamma<0$ indicates asymmetric volatility, $|a_{21}|>0$ and $|d_{21}|>0$ show spillovers and asymmetric spillovers, respectively. * indicates the significance at the 5% level. Ukraine, Vietnam and Zimbabwe are the frontier markets. The estimation results of the ADCC models are provided upon request.

Table 5. Cross-market models – Asymmetric volatility and asymmetric spillovers (BEKK)

*Panel A: Asymmetric Volatility in the BEKK*

| | Full | | | | 2007- | | | | 2008- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN: | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx |
| NgR | -0.022 | -0.023 | -0.029** | -0.023 | 0.018 | 0.013 | 0.011 | 0.017 | 0.000 | 0.003 | 0.003 | 0.001 |
| | *-1.404* | *-1.427* | *-1.979* | *-1.506* | *1.496* | *1.142* | *0.930* | *1.418* | *0.020* | *0.267* | *0.265* | *0.095* |
| SdR | -0.044*** | -0.043*** | -0.044*** | -0.043*** | -0.025* | -0.011 | -0.034** | -0.023* | 0.007 | 0.012 | 0.002 | 0.007 |
| | *-13.098* | *-12.459* | *-12.855* | *-13.063* | *-1.755* | *-0.738* | *-2.195* | *-1.650* | *0.459* | *0.749* | *0.105* | *0.474* |
| SkR | -0.058*** | -0.058*** | -0.056*** | -0.058*** | -0.004 | -0.004 | -0.009 | -0.004 | 0.020** | 0.020** | 0.018** | 0.020** |
| | *-9.598* | *-9.283* | *-9.346* | *-9.707* | *-0.521* | *-0.525* | *-0.980* | *-0.487* | *2.477* | *2.363* | *2.194* | *2.456* |
| lnKm | 0.022 | 0.024 | 0.023 | 0.026 | 0.011 | 0.010 | 0.015 | 0.013 | -0.005 | -0.006 | -0.005 | -0.004 |
| | *1.163* | *1.258* | *1.206* | *1.393* | *0.872* | *0.794* | *1.082* | *0.996* | *-0.354* | *-0.466* | *-0.374* | *-0.314* |
| IN | -0.001** | -0.001 | 0.000** | -0.009*** | -0.001*** | -0.001*** | -4E-04** | -0.011*** | -4E-04** | -4E-04 | -2E-04 | -0.006* |
| | *-2.418* | *-1.389* | *-2.220* | *-2.587* | *-3.557* | *-3.231* | *-2.561* | *-3.834* | *-2.054* | *-1.274* | *-1.180* | *-1.854* |
| $IN^2$ | 1E-06* | 3E-06 | 5E-07* | 4E-04* | 1E-06*** | 4E-06** | 4E-07** | 4E-04*** | 7E-07* | 2E-06 | 2E-07 | 2E-04 |
| | *1.855* | *1.150* | *1.876* | *1.883* | *3.347* | *2.406* | *2.511* | *3.539* | *1.851* | *0.870* | *1.127* | *1.609* |
| $AdjR^2$ | 0.835 | 0.832 | 0.832 | 0.844 | 0.172 | 0.180 | 0.085 | 0.199 | 0.066 | 0.035 | 0.016 | 0.053 |

*Panel B: Asymmetric Spillovers in the BEKK*

| | Full | | | | 2007- | | | | 2008- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN: | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx |
| NgR | -0.063* | -0.080** | -0.062* | -0.061* | -0.134 | -0.143 | -0.116 | -0.125 | -0.037 | -0.049 | -0.044 | -0.042 |
| | *-1.885* | *-2.214* | *-1.932* | *-1.772* | *-1.277* | *-1.335* | *-1.103* | *-1.191* | *-0.478* | *-0.667* | *-0.595* | *-0.545* |
| SdR | 0.052*** | 0.052*** | 0.052*** | 0.052*** | 0.148 | 0.097 | 0.206 | 0.139 | 0.163* | 0.142 | 0.214** | 0.162* |
| | *7.170* | *6.851* | *7.170* | *6.959* | *1.170* | *0.712* | *1.571* | *1.094* | *1.812* | *1.538* | *2.387* | *1.791* |
| SkR | -0.015 | -0.014 | -0.017 | -0.016 | -0.067 | -0.061 | -0.049 | -0.066 | -0.017 | -0.009 | -0.013 | -0.017 |
| | *-1.129* | *-0.989* | *-1.274* | *-1.200* | *-0.886* | *-0.780* | *-0.649* | *-0.870* | *-0.342* | *-0.186* | *-0.259* | *-0.334* |
| lnKm | 0.007 | 0.019 | 0.003 | 0.003 | -0.299*** | -0.274** | -0.314*** | -0.305*** | -0.218*** | -0.204** | -0.233*** | -0.220*** |
| | *0.161* | *0.444* | *0.078* | *0.076* | *-2.626* | *-2.339* | *-2.703* | *-2.662* | *-2.607* | *-2.510* | *-2.815* | *-2.612* |
| IN | 5E-04 | 0.002* | 3E-04 | 0.005 | 0.003* | 0.003 | 0.002 | 0.046* | 0.002 | 0.004** | 0.002* | 0.023 |
| | *0.868* | *1.734* | *0.743* | *0.655* | *1.921* | *1.060* | *1.362* | *1.852* | *1.441* | *2.101* | *1.727* | *1.267* |
| $IN^2$ | 5E-07 | -1E-05* | 9E-08 | 4E-04 | -3E-06 | -1E-05 | -1E-06 | -0.001 | -3E-06 | -2E-05** | -2E-06 | -8E-04 |
| | *0.343* | *-1.816* | *0.168* | *0.864* | *-1.166* | *-0.625* | *-0.867* | *-0.858* | *-1.251* | *-2.190* | *-1.582* | *-1.043* |
| $AdjR^2$ | 0.517 | 0.494 | 0.523 | 0.516 | 0.134 | 0.070 | 0.106 | 0.125 | 0.104 | 0.144 | 0.127 | 0.097 |

Note: This table presents the results of the cross-market model with asymmetric volatility and asymmetric spillovers as dependent variables. IN is the measures of trade intensity. 'Trad', 'Tovr', 'Mkcp' and 'Tidx' indicate the total value of stock traded per GDP, the turnover ratio, market capitalisation per GDP and the trade intensity index are used as IN, respectively. Numbers in italic are t-statistics. Note that the level of asymmetric volatility (Panel A) is measured as negative values. Due to data limitation in some trade intensity measures (Table 2), 65 and 62 countries are utilised in the full and two post-crisis periods (post-2007 and post-2008), respectively. $IN^2$ is the square of IN. If the coefficient of $IN^2$ has the opposite sign to that of IN, trade intensity is eventually negatively related to asymmetric volatility. However, it happens only at a very high level of trade intensity, e.g., over the trade intensity index of 10-13, where only one market (Hong Kong) in our sample is located. NgR is the strength of negative return, SdR is the standard deviation and SkR is the skewness of return. lnKm is the distance from the US.

Table 6. Cross-market models - Asymmetric spillovers (ADCC) and symmetric spillovers (BEKK)

*Panel A: Symmetric Spillovers in the BEKK*

| | Full | | | | 2007- | | | | 2008- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN: | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx |
| NgR | -0.021 | -0.034 | -0.030 | -0.019 | -0.059 | -0.044 | -0.046 | -0.053 | -0.146 | -0.155$^{*}$ | -0.156$^{*}$ | -0.154$^{*}$ |
| | *-0.376* | *-0.574* | *-0.547* | *-0.317* | *-1.059* | *-0.811* | *-0.780* | *-0.954* | *-1.601* | *-1.735* | *-1.785* | *-1.689* |
| SdR | 0.024$^{*}$ | 0.024$^{*}$ | 0.024$^{*}$ | 0.024$^{*}$ | 0.109 | 0.039 | 0.157$^{**}$ | 0.100 | 0.005 | 0.025 | 0.013 | 0.009 |
| | *1.929* | *1.890* | *1.886* | *1.869* | *1.620* | *0.559* | *2.129* | *1.507* | *0.051* | *0.222* | *0.117* | *0.081* |
| SkR | -0.019 | -0.016 | -0.018 | -0.018 | -0.036 | -0.040 | -0.020 | -0.037 | -0.048 | -0.045 | -0.049 | -0.046 |
| | *-0.844* | *-0.686* | *-0.826* | *-0.807* | *-0.905* | *-1.017* | *-0.484* | *-0.944* | *-0.810* | *-0.764* | *-0.839* | *-0.769* |
| lnKm | -0.119$^{*}$ | -0.116$^{*}$ | -0.123$^{*}$ | -0.123$^{*}$ | -0.100$^{*}$ | -0.096 | -0.108$^{*}$ | -0.106$^{*}$ | 0.051 | 0.044 | 0.047 | 0.053 |
| | *-1.727* | *-1.656* | *-1.778* | *-1.745* | *-1.646* | *-1.612* | *-1.664* | *-1.769* | *0.510* | *0.453* | *0.476* | *0.530* |
| IN | 1E-04 | 0.002 | -2E-05 | 0.004 | 0.003$^{***}$ | 0.004$^{**}$ | 0.001$^{*}$ | 0.048$^{***}$ | 6E-05 | -0.001 | -4E-05 | -0.006 |
| | *0.154* | *1.043* | *-0.027* | *0.316* | *3.484* | *2.502* | *1.943* | *3.652* | *0.038* | *-0.564* | *-0.033* | *-0.254* |
| $IN^2$ | 6E-08 | -9E-06 | 2E-07 | -3E-05 | -5E-06$^{***}$ | -1E-05 | -1E-06$^{*}$ | -0.002$^{***}$ | -6E-07 | 6E-06 | -1E-07 | -3E-05 |
| | *0.023* | *-0.945* | *0.162* | *-0.034* | *-3.222* | *-1.366* | *-1.908* | *-3.270* | *-0.231* | *0.461* | *-0.124* | *-0.030* |
| $AdjR^2$ | 0.100 | 0.112 | 0.104 | 0.099 | 0.162 | 0.178 | 0.051 | 0.177 | -0.032 | -0.031 | -0.024 | -0.031 |

*Panel B: Asymmetric Spillovers (Correlation) in the ADCC*

| | Full | | | | 2007- | | | | 2008- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN: | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx |
| NgR | -0.005 | -0.004 | -0.005 | -0.005 | -0.004 | -0.007 | -0.005 | -0.004 | 0.004 | 0.003 | 0.002 | 0.004 |
| | *-1.309* | *-1.077* | *-1.425* | *-1.337* | *-0.803* | *-1.127* | *-0.902* | *-0.781* | *0.895* | *0.719* | *0.535* | *0.873* |
| SdR | 0.001 | 0.001 | 0.001 | 0.001 | -0.013$^{*}$ | -0.014$^{*}$ | -0.012$^{*}$ | -0.013$^{*}$ | -0.008 | -0.009 | -0.009$^{*}$ | -0.008 |
| | *1.351* | *1.333* | *1.344* | *1.330* | *-1.894* | *-1.834* | *-1.664* | *-1.923* | *-1.609* | *-1.524* | *-1.765* | *-1.583* |
| SkR | 0.003$^{**}$ | 0.003$^{**}$ | 0.004$^{**}$ | 0.004$^{**}$ | 0.004 | 0.004 | 0.004 | 0.004 | -0.003 | -0.004 | -0.003 | -0.003 |
| | *2.385* | *2.240* | *2.453* | *2.373* | *0.958* | *0.905* | *0.982* | *0.952* | *-1.080* | *-0.993* | *-0.972* | *-1.050* |
| lnKm | 0.007 | 0.007 | 0.007 | 0.007 | 0.018$^{***}$ | 0.020$^{***}$ | 0.018$^{***}$ | 0.018$^{***}$ | 0.009$^{*}$ | 0.010$^{*}$ | 0.009$^{*}$ | 0.009$^{*}$ |
| | *1.546* | *1.444* | *1.534* | *1.479* | *3.160* | *3.285* | *3.138* | *3.144* | *1.726* | *1.779* | *1.813* | *1.742* |
| IN | -1E-05 | -1E-04 | -6E-07 | 2E-04 | 3E-05 | 1E-04 | 2E-05 | 7E-04 | -5E-05 | 2E-05 | -8E-05 | -6E-04 |
| | *-0.213* | *-1.195* | *-0.014* | *0.175* | *0.309* | *0.610* | *0.343* | *0.508* | *-0.725* | *0.182* | *-1.457* | *-0.638* |
| $IN^2$ | 8E-08 | 9E-07 | 2E-08 | 2E-05 | 9E-08 | -5E-07 | 2E-08 | 4E-05 | 2E-07$^{*}$ | -8E-08 | 1E-07$^{**}$ | 8E-05$^{**}$ |
| | *0.496* | *1.427* | *0.261* | *0.291* | *0.632* | *-0.446* | *0.325* | *0.750* | *1.780* | *-0.123* | *2.211* | *2.028* |
| $AdjR^2$ | 0.078 | 0.102 | 0.085 | 0.073 | 0.266 | 0.175 | 0.260 | 0.266 | 0.173 | 0.013 | 0.179 | 0.174 |

Note: This table presents the results of the cross-market model with asymmetric volatility from ADCC and symmetric part of the spillovers from the BEKK as dependent variables. IN is the measures of trade intensity. 'Trad', 'Tovr', 'Mkcp' and 'Tidx' indicate the total value of stock traded per GDP, the turnover ratio, market capitalisation per GDP and the trade intensity index are used as IN, respectively. Numbers in italics are t-statistics. Due to data limitation in some trade intensity measures (Table 2), 65 and 62 countries are utilised in the full and two post-crisis periods (post-2007 and post-2008), respectively. $IN^2$ is the square of IN. NgR is the strength of negative return, SdR is the standard deviation and SkR is the skewness of return. lnKm is the distance from the US.

## Table 7. Cross-market models - uni-directional spillover index (VD and HD)

*Panel A: Uni-directional Spillover Index from Variance Decomposition*

| | Full | | | | 2007- | | | | 2008- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN: | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx |
| NgR | -0.504 | -1.500 | 0.172 | -0.093 | -3.321 | -2.329 | -1.760 | -2.764 | -1.919 | -3.426 | -3.527 | -1.825 |
| | *-0.188* | *-0.517* | *0.061* | *-0.034* | *-1.198* | *-0.762* | *-0.620* | *-1.013* | *-0.682* | *-1.170* | *-1.271* | *-0.662* |
| SdR | -0.441 | -0.724 | -0.448 | -0.515 | 8.040** | 3.647 | 13.857*** | 7.318** | 6.735** | 3.260 | 12.382*** | 6.314* |
| | *-0.756* | *-1.182* | *-0.692* | *-0.864* | *2.400* | *0.935* | *3.900* | *2.212* | *2.056* | *0.887* | *3.639* | *1.960* |
| SkR | -2.365** | -2.082* | -2.563** | -2.321** | -1.038 | -0.737 | 0.326 | -1.115 | -0.295 | -0.024 | 0.482 | -0.490 |
| | *-2.248* | *-1.864* | *-2.224* | *-2.158* | *-0.521* | *-0.330* | *0.160* | *-0.568* | *-0.162* | *-0.012* | *0.260* | *-0.273* |
| lnKm | -19.662*** | -19.688*** | -20.628*** | -20.609*** | -19.791*** | -18.964*** | -21.474*** | -20.338*** | -19.620*** | -18.508*** | -20.905*** | -20.091*** |
| | *-6.045* | *-5.744* | *-5.745* | *-6.208* | *-6.570* | *-5.662* | *-6.829* | *-6.833* | *-6.439* | *-5.741* | *-6.671* | *-6.703* |
| IN | 0.242*** | 0.388*** | 0.154*** | 3.466*** | 0.244*** | 0.294*** | 0.195*** | 3.999*** | 0.246*** | 0.299*** | 0.184*** | 3.703*** |
| | *5.547* | *4.614* | *4.105* | *5.516* | *5.912* | *3.519* | *5.464* | *6.189* | *5.280* | *3.771* | *4.839* | *5.615* |
| $IN^2$ | -5E-04*** | -0.002*** | -2E-04*** | -0.150*** | -4E-04*** | -0.001** | -2E-04*** | -0.143*** | -4E-04*** | -0.001*** | -2E-04*** | -0.127*** |
| | *-4.224* | *-3.723* | *-3.395* | *-3.886* | *-5.011* | *-2.412* | *-4.920* | *-4.949* | *-4.580* | *-2.719* | *-4.430* | *-4.637* |
| $AdjR^2$ | 0.529 | 0.493 | 0.433 | 0.524 | 0.566 | 0.457 | 0.536 | 0.578 | 0.545 | 0.485 | 0.524 | 0.562 |

*Panel B: Uni-directional Spillover Index from Historical Decomposition*

| | Full | | | | 2007- | | | | 2008- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN: | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx |
| NgR | -0.006 | -0.068 | -0.277 | 0.069 | 0.032 | 0.139 | 0.033 | 0.047 | -0.308 | -0.255 | -0.412 | -0.263 |
| | *-0.018* | *-0.221* | *-0.783* | *0.219* | *0.108* | *0.487* | *0.113* | *0.165* | *-0.926* | *-0.790* | *-1.283* | *-0.806* |
| SdR | 0.023 | 0.019 | 0.041 | 0.031 | 0.668* | 0.408 | 1.041*** | 0.635* | 0.555 | 0.293 | 0.883** | 0.520 |
| | *0.330* | *0.291* | *0.502* | *0.457* | *1.887* | *1.116* | *2.828* | *1.831* | *1.433* | *0.724* | *2.242* | *1.366* |
| SkR | -0.423*** | -0.400*** | -0.402*** | -0.428*** | 0.346* | 0.334 | 0.380* | 0.332 | 0.231 | 0.212 | 0.257 | 0.210 |
| | *-3.323* | *-3.353* | *-2.788* | *-3.476* | *1.646* | *1.594* | *1.796* | *1.610* | *1.071* | *0.985* | *1.200* | *0.991* |
| lnKm | -0.920** | -0.912** | -1.008** | -0.964** | -0.663** | -0.672** | -0.743** | -0.691** | -0.688* | -0.685* | -0.783** | -0.720 |
| | *-2.340* | *-2.490* | *-2.243* | *-2.537* | *-2.082* | *-2.144* | *-2.281* | *-2.215* | *-1.910* | *-1.927* | *-2.159* | *-2.035* |
| IN | 0.010* | 0.030*** | 0.010** | 0.204*** | 0.010** | 0.019** | 0.010*** | 0.186*** | 0.012** | 0.019** | 0.010** | 0.204 |
| | *1.950* | *3.313* | *2.051* | *2.837* | *2.272* | *2.393* | *2.733* | *2.741* | *2.167* | *2.227* | *2.186* | *2.613* |
| $IN^2$ | -2E-05* | -1E-04*** | -1E-05* | -0.010** | -2E-05** | -8E-05* | -1E-05*** | -0.009*** | -2E-05** | -7E-05 | -1E-05** | -0.009 |
| | *-1.658* | *-2.702* | *-1.828* | *-2.293* | *-2.441* | *-1.800* | *-2.851* | *-2.904* | *-2.385* | *-1.579* | *-2.363* | *-2.845* |
| $AdjR^2$ | 0.196 | 0.319 | 0.148 | 0.267 | 0.179 | 0.195 | 0.201 | 0.214 | 0.140 | 0.154 | 0.154 | 0.173 |

Note: This table presents the results of the cross-market model with the uni-directional spillover index, calculated from variance decomposition (Panel A) and historical decomposition (Panel B), as dependent variables. This uni-directional spillover index measures the impact of the US market on the recipient market. IN is the measures of trade intensity. 'Trad', 'Tovr', 'Mkcp' and 'Tidx' indicate the total value of stock traded per GDP, the turnover ratio, market capitalisation per GDP and the trade intensity index are used as IN, respectively. Numbers in italics are t-statistics. Due to data limitation in some trade intensity measures (Table 2), 65 and 62 countries are utilised in the full and two post-crisis periods (post-2007 and post-2008), respectively. $IN^2$ is the square of IN. NgR is the strength of negative return, SdR is the standard deviation and SkR is the skewness of return. lnKm is the distance from the US.

## Table 8. Cross-market models - bi-directional and net spillover index (VD)

*Panel A: Bi-directional Spillover Index from Variance Decomposition*

| | Full | | | | 2007- | | | | 2008- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN: | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx |
| NgR | -0.533 | -1.531 | 0.129 | -0.116 | -3.336 | -2.330 | -1.773 | -2.778 | -1.953 | -3.450 | -3.571 | -1.852 |
| | *-0.199* | *-0.527* | *0.045* | *-0.042* | *-1.201* | *-0.761* | *-0.624* | *-1.016* | *-0.692* | *-1.176* | *-1.283* | *-0.670* |
| SdR | -0.437 | -0.721 | -0.443 | -0.510 | 8.066** | 3.644 | 13.927*** | 7.341** | 6.765** | 3.254 | 12.451*** | 6.339** |
| | *-0.746* | *-1.173* | *-0.681* | *-0.854* | *2.402* | *0.932* | *3.911* | *2.215* | *2.059* | *0.883* | *3.648* | *1.963* |
| SkR | -2.388** | -2.102* | -2.584** | -2.343** | -1.014 | -0.715 | 0.355 | -1.093 | -0.263 | 0.004 | 0.518 | -0.461 |
| | *-2.259* | *-1.876* | *-2.233* | *-2.171* | *-0.508* | *-0.319* | *0.174* | *-0.555* | *-0.144* | *0.002* | *0.279* | *-0.256* |
| lnKm | -19.832*** | -19.861*** | -20.804*** | -20.783*** | -19.944*** | -19.121*** | -21.637*** | -20.494*** | -19.796*** | -18.685*** | -21.090*** | -20.271*** |
| | *-6.071* | *-5.779* | *-5.770* | *-6.239* | *-6.604* | *-5.697* | *-6.865* | *-6.874* | *-6.477* | *-5.783* | *-6.709* | *-6.750* |
| IN | 0.243*** | 0.391*** | 0.154*** | 3.482*** | 0.245*** | 0.296*** | 0.196*** | 4.022*** | 0.248*** | 0.301*** | 0.185*** | 3.731*** |
| | *5.539* | *4.631* | *4.106* | *5.522* | *5.927* | *3.532* | *5.486* | *6.214* | *5.298* | *3.793* | *4.856* | *5.647* |
| $IN^2$ | -5E-04*** | -0.002*** | -2E-04*** | -0.151*** | -4E-04*** | -0.001** | -2E-04*** | -0.144*** | -4E-04*** | -0.001*** | -2E-04*** | -0.128*** |
| | *-4.224* | *-3.738* | *-3.401* | *-3.898* | *-5.032* | *-2.420* | *-4.948* | *-4.982* | *-4.606* | *-2.732* | *-4.452* | *-4.676* |
| $AdjR^2$ | 0.530 | 0.496 | 0.434 | 0.526 | 0.568 | 0.460 | 0.538 | 0.580 | 0.548 | 0.489 | 0.527 | 0.565 |

*Panel A: Net Spillover Index from Variance Decomposition*

| | Full | | | | 2007- | | | | 2008- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN: | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx | Trad | Tovr | Mkcp | Tidx |
| NgR | -0.474 | -1.468 | 0.216 | -0.071 | -3.306 | -2.329 | -1.746 | -2.750 | -1.884 | -3.401 | -3.482 | -1.799 |
| | *-0.178* | *-0.508* | *0.077* | *-0.026* | *-1.195* | *-0.764* | *-0.617* | *-1.009* | *-0.672* | *-1.164* | *-1.258* | *-0.654* |
| SdR | -0.445 | -0.728 | -0.453 | -0.519 | 8.013** | 3.650 | 13.788*** | 7.296** | 6.704** | 3.267 | 12.314*** | 6.290* |
| | *-0.766* | *-1.190* | *-0.702* | *-0.875* | *2.398* | *0.937* | *3.888* | *2.209* | *2.052* | *0.890* | *3.629* | *1.955* |
| SkR | -2.343** | -2.063* | -2.543** | -2.299** | -1.062 | -0.759 | 0.298 | -1.137 | -0.326 | -0.052 | 0.446 | -0.518 |
| | *-2.236* | *-1.851* | *-2.215* | *-2.145* | *-0.535* | *-0.340* | *0.146* | *-0.580* | *-0.179* | *-0.027* | *0.242* | *-0.289* |
| lnKm | -19.493*** | -19.515*** | -20.453*** | -20.434*** | -19.638*** | -18.807*** | -21.311*** | -20.181*** | -19.445*** | -18.331*** | -20.720*** | -19.911*** |
| | *-6.018* | *-5.708* | *-5.719* | *-6.175* | *-6.534* | *-5.626* | *-6.790* | *-6.790* | *-6.398* | *-5.697* | *-6.630* | *-6.654* |
| IN | 0.241*** | 0.386*** | 0.153*** | 3.451*** | 0.242*** | 0.293*** | 0.194*** | 3.976*** | 0.244*** | 0.296*** | 0.183*** | 3.675*** |
| | *5.553* | *4.597* | *4.102* | *5.509* | *5.897* | *3.506* | *5.440* | *6.162* | *5.259* | *3.748* | *4.820* | *5.582* |
| $IN^2$ | -5E-04*** | -2E-03*** | -2E-04*** | -1E-01*** | -4E-04*** | -1E-03** | -2E-04*** | -1E-01*** | -4E-04*** | -1E-03*** | -2E-04*** | -1E-01*** |
| | *-4.223* | *-3.708* | *-3.389* | *-3.872* | *-4.988* | *-2.404* | *-4.892* | *-4.915* | *-4.552* | *-2.705* | *-4.405* | *-4.596* |
| $AdjR^2$ | 0.528 | 0.490 | 0.431 | 0.522 | 0.564 | 0.454 | 0.533 | 0.575 | 0.542 | 0.481 | 0.521 | 0.558 |

Note: This table presents the results of the cross-market model with the bi-directional and the net spillover index, calculated from variance decomposition, as dependent variables. The bi-directional index is the sum of two uni-directional indices and the net spillover index is their difference. IN is the measures of trade intensity. 'Trad', 'Tovr', 'Mkcp' and 'Tidx' indicate the total value of stock traded per GDP, the turnover ratio, market capitalisation per GDP and the trade intensity index are used as IN, respectively. Numbers in italics are t-statistics. Due to data limitation in some trade intensity measures (Table 2), 65 and 62 countries are utilised in the full and two post-crisis periods (post-2007 and post-2008), respectively. $IN^2$ is the square of IN. NgR is the strength of negative return, SdR is the standard deviation and SkR is the skewness of return. lnKm is the distance from the US.

Table 9. Cross-market model - quantile regression of asymmetric volatility

| | | Full | | | 2007- | | | 2008- | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.1 | 0.5 | 0.9 | 0.1 | 0.5 | 0.9 | 0.1 | 0.5 | 0.9 |
| Trad | NgR | -0.017 | -0.032 * | -0.047 ** | 0.013 | 0.005 | -0.036 | 0.045 ** | 0.012 | 0.017 |
| | | -0.970 | -1.760 | -2.526 | 0.790 | 0.282 | -1.471 | 2.206 | 0.939 | 1.195 |
| | SdR | -0.042 *** | -0.045 *** | -0.050 *** | 0.015 | 0.006 | 0.004 | -0.048 | -0.025 * | -0.044 *** |
| | | -16.451 | -13.904 | -17.913 | 0.780 | 0.240 | 0.150 | -1.567 | -1.840 | -2.934 |
| | SkR | -0.062 *** | -0.055 | -0.025 | 0.007 | 0.018 * | 0.034 *** | -0.007 | 0.013 | 0.002 |
| | | -14.954 | -1.319 | -1.323 | 0.665 | 1.736 | 3.511 | -0.555 | 0.878 | 0.149 |
| | lnKm | 0.004 | 0.021 | 0.006 | -0.004 | 0.008 | -0.038 | 0.058 | 0.014 | -0.019 |
| | | 0.190 | 0.897 | 0.216 | -0.246 | 0.447 | -1.138 | 1.286 | 1.076 | -0.696 |
| | IN | -7E-05 | -6E-04 * | -7E-04 ** | -3E-04 | -4E-04 | -3E-04 | -5E-04 ** | -6E-04 *** | -4E-04 * |
| | | -0.212 | -1.825 | -2.298 | -1.148 | -1.504 | -0.594 | -2.426 | -2.918 | -1.843 |
| | $IN^2$ | 4E-07 | 1E-06 | 1E-06 | 7E-07 | 7E-07 | 3E-07 | 1E-06 *** | 1E-06 *** | 6E-07 * |
| | | 0.567 | 1.556 | 1.615 | 1.540 | 1.482 | 0.346 | 2.895 | 2.860 | 1.694 |
| | $AdjR^2$ | 0.649 | 0.281 | 0.241 | 0.001 | 0.014 | 0.094 | 0.038 | 0.095 | 0.084 |
| Tovr | NgR | -0.009 | -0.019 | -0.026 | 0.010 | 0.009 | -0.042 | 0.002 | 0.009 | 0.005 |
| | | -0.454 | -1.183 | -1.492 | 0.583 | 0.528 | -1.619 | 0.092 | 0.667 | 0.220 |
| | SdR | -0.037 *** | -0.043 *** | -0.048 *** | 0.014 | 0.041 | -0.001 | 0.033 | -0.014 | -0.014 |
| | | -8.943 | -14.148 | -19.112 | 0.696 | 1.453 | -0.021 | 1.187 | -0.900 | -0.417 |
| | SkR | -0.055 *** | -0.058 | -0.024 | 0.006 | 0.021 ** | 0.035 *** | -0.023 | 0.010 | -0.012 |
| | | -9.015 | -1.291 | -1.336 | 0.538 | 2.094 | 3.380 | -1.148 | 0.915 | -0.288 |
| | lnKm | 0.044 | 0.028 | 0.017 | -0.009 | 0.005 | -0.031 | 0.012 | 0.014 | -0.014 |
| | | 1.194 | 1.334 | 0.670 | -0.643 | 0.342 | -0.922 | 0.334 | 1.142 | -0.485 |
| | IN | 0.001 | -0.001 * | -0.002 ** | 0.000 | -0.001 | 0.000 | 0.000 | -0.001 *** | -0.002 * |
| | | 1.052 | -1.778 | -2.060 | -0.721 | -1.357 | 0.100 | -0.250 | -3.264 | -1.709 |
| | $IN^2$ | -1E-06 | 6E-06 | 1E-05 | 2E-06 | 2E-06 | -2E-06 | 5E-07 | 5E-06 ** | 7E-06 * |
| | | -0.557 | 1.495 | 1.469 | 0.962 | 0.971 | -0.832 | 0.184 | 2.664 | 1.702 |
| | $AdjR^2$ | 0.696 | 0.298 | 0.304 | 0.000 | -0.010 | 0.115 | -0.030 | 0.099 | 0.186 |
| Mkcp | NgR | -0.011 | -0.043 *** | -0.031 | 0.015 | 0.007 | -0.051 * | 0.012 | 0.007 | 0.015 |
| | | -0.596 | -2.711 | -1.215 | 0.965 | 0.385 | -1.793 | 0.318 | 0.415 | 0.815 |
| | SdR | -0.043 *** | -0.044 *** | -0.051 *** | 0.014 | 0.002 | -0.006 | -0.020 | -0.033 * | -0.061 * |
| | | -16.496 | -14.232 | -17.864 | 0.747 | 0.089 | -0.286 | -0.422 | -1.899 | -1.821 |
| | SkR | -0.063 *** | -0.053 | -0.023 | 0.002 | 0.018 * | 0.031 *** | -0.004 | -0.001 | -0.010 |
| | | -15.659 | -1.562 | -1.411 | 0.201 | 1.733 | 3.384 | -0.057 | -0.106 | -0.296 |
| | lnKm | -0.009 | 0.030 | -0.002 | -0.012 | 0.015 | -0.037 | 0.033 | 0.013 | -0.013 |
| | | -0.378 | 1.396 | -0.086 | -0.677 | 0.841 | -0.975 | 0.454 | 0.917 | -0.409 |
| | IN | 0.000 | -0.001 ** | -0.001 ** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 ** | -0.001 * |
| | | -1.245 | -2.144 | -2.010 | -1.030 | -0.947 | 0.196 | -0.939 | -2.353 | -1.755 |
| | $IN^2$ | 5E-07 | 6E-07 * | 5E-07 | 3E-07 | 2E-07 | -2E-07 | 3E-07 | 5E-07 ** | 4E-07 * |
| | | 1.542 | 1.955 | 1.558 | 1.265 | 0.921 | -0.328 | 1.317 | 2.417 | 1.701 |
| | $AdjR^2$ | 0.647 | 0.295 | 0.213 | 0.018 | -0.024 | 0.065 | 0.012 | 0.020 | 0.096 |
| Tidx | NgR | -0.021 | -0.029 * | -0.044 ** | 0.011 | 0.004 | -0.038 | 0.032 | 0.019 | 0.014 |
| | | -1.134 | -1.715 | -2.209 | 0.655 | 0.211 | -1.520 | 1.642 | 1.392 | 0.890 |
| | SdR | -0.042 *** | -0.043 *** | -0.050 *** | 0.014 | 0.013 | -0.001 | -0.008 | -0.028 * | -0.040 ** |
| | | -15.441 | -14.436 | -16.629 | 0.740 | 0.471 | -0.045 | -0.452 | -1.958 | -2.541 |
| | SkR | -0.061 *** | -0.057 | -0.024 | 0.005 | 0.019 * | 0.035 *** | 0.011 | 0.009 | -0.001 |
| | | -13.492 | -1.305 | -1.260 | 0.437 | 1.833 | 3.415 | 0.365 | 0.777 | -0.101 |
| | lnKm | 0.006 | 0.030 | 0.005 | -0.007 | 0.010 | -0.032 | 0.056 | 0.012 | -0.019 |
| | | 0.284 | 1.457 | 0.165 | -0.445 | 0.560 | -0.927 | 1.432 | 0.889 | -0.681 |
| | IN | 0.002 | -0.009 * | -0.009 ** | -0.003 | -0.006 | -0.006 | -0.011 *** | -0.012 *** | -0.008 ** |
| | | 0.285 | -1.732 | -2.063 | -0.712 | -1.403 | -0.769 | -3.060 | -3.332 | -2.101 |
| | $IN^2$ | 3E-05 | 4E-04 | 3E-04 | 2E-04 | 2E-04 | 1E-04 | 5E-04 *** | 5E-04 *** | 3E-04 * |
| | | 0.114 | 1.447 | 1.195 | 1.250 | 1.369 | 0.386 | 3.721 | 3.321 | 1.911 |
| | $AdjR^2$ | 0.667 | 0.325 | 0.294 | -0.007 | 0.013 | 0.096 | 0.071 | 0.114 | 0.091 |

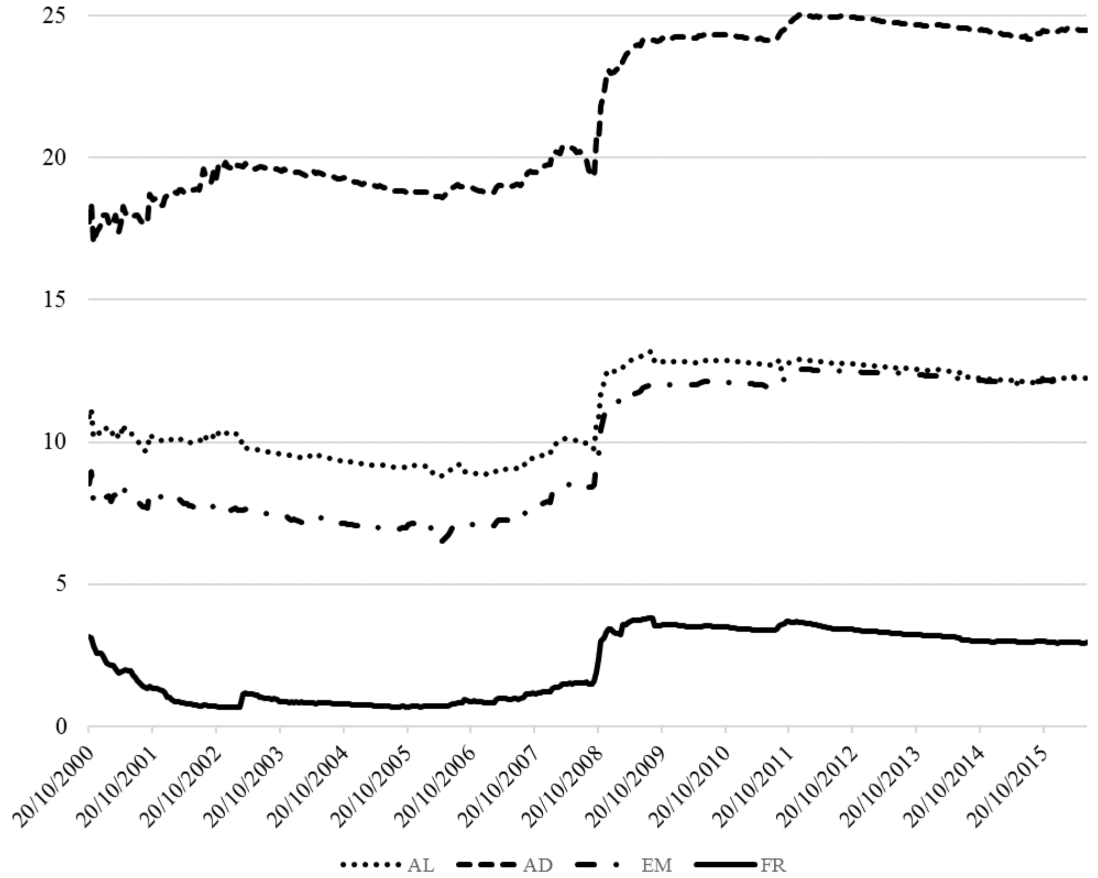
Note: This table presents the estimation results of the cross-market model by the quantile regression method. Asymmetric volatility, measured in the BEKK, is used as dependent variables. IN is the measures of trade intensity. ‘Trad’, 'Tovr', ‘Mkcp’ and ‘Tidx’ indicate the total value of stock traded per GDP, the turnover ratio, market capitalisation per GDP and the trade intensity index are used as IN, respectively. $IN^2$ is the squared value of IN. Numbers in italics are t-statistics. Due to data limitation in some trade intensity measures (Table 2), 65 and 62 countries are utilised in the full and two post-crisis periods (post-2007 and post-2008), respectively. 0.1, 0.5 and 0.9 are three quantiles used in this regression. NgR is the strength of negative return, SdR is the standard deviation and SkR is the skewness of return. lnKm is the distance from the US.

Table 10. Cross-market model - quantile regression of net spillovers (VD)

| | | Full | | | 2007- | | | 2008- | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.1 | 0.5 | 0.9 | 0.1 | 0.5 | 0.9 | 0.1 | 0.5 | 0.9 |
| Trad | NgR | 3.193 | 1.892 | -8.891* | 0.604 | -0.167 | -7.480 | 1.422 | -0.395 | -11.740*** |
| | | 1.378 | 0.704 | -1.998 | 0.220 | -0.051 | -1.527 | 0.513 | -0.106 | -2.917 |
| | SdR | 1.537*** | 0.519 | -2.687*** | 5.345* | 4.164 | 2.004 | 6.844** | 5.371 | 0.915 |
| | | 3.776 | 0.846 | -2.668 | 1.713 | 1.042 | 0.356 | 2.217 | 1.305 | 0.226 |
| | SkR | 0.067 | -1.291 | -4.334 | 0.421 | 0.536 | 1.030 | -0.475 | 0.462 | 0.064 |
| | | 0.112 | -1.569 | -0.498 | 0.344 | 0.323 | 0.496 | -0.392 | 0.252 | 0.035 |
| | lnKm | -0.920 | -9.225* | -33.227*** | -1.928 | -13.646*** | -29.911** | -3.922 | -15.057*** | -32.050*** |
| | | -0.256 | -1.728 | -4.112 | -0.300 | -3.236 | -2.196 | -0.655 | -3.643 | -5.435 |
| | IN | 0.142*** | 0.197*** | 0.196** | 0.139*** | 0.199*** | 0.285** | 0.146*** | 0.202*** | 0.369*** |
| | | 3.808 | 4.753 | 2.063 | 2.989 | 3.378 | 2.024 | 4.028 | 3.831 | 3.181 |
| | $IN^2$ | -2E-04*** | -4E-04*** | -4E-04** | -2E-04** | -3E-04*** | -5E-04** | -2E-04*** | -3E-04*** | -6E-04*** |
| | | -2.736 | -3.716 | -2.179 | -2.384 | -2.998 | -2.038 | -3.114 | -3.262 | -3.203 |
| | $AdjR^2$ | 0.219 | 0.320 | 0.386 | 0.194 | 0.308 | 0.415 | 0.256 | 0.336 | 0.442 |
| Tovr | NgR | 4.234** | -1.035 | -5.024 | 1.374 | -2.186 | -12.129* | 2.913 | 2.204 | -14.419*** |
| | | 2.007 | -0.323 | -1.004 | 0.430 | -0.639 | -1.762 | 0.814 | 0.525 | -3.055 |
| | SdR | 0.935** | 0.235 | -1.800 | 4.188 | 3.311 | -0.674 | 5.932 | 3.114 | -4.150 |
| | | 2.443 | 0.307 | -1.548 | 1.114 | 0.714 | -0.101 | 1.428 | 0.621 | -1.047 |
| | SkR | -0.150 | -1.023 | -4.506** | -0.369 | 0.921 | 0.090 | -0.395 | 0.834 | 2.224 |
| | | -0.269 | -1.046 | -2.630 | -0.286 | 0.539 | 0.038 | -0.265 | 0.396 | 1.050 |
| | lnKm | -6.543* | -9.430 | -23.174** | -2.938 | -10.947*** | -31.219* | -4.383 | -14.326*** | -36.783*** |
| | | -1.849 | -1.437 | -2.296 | -0.411 | -2.736 | -1.722 | -0.620 | -3.012 | -6.733 |
| | IN | 0.255*** | 0.440*** | 0.310** | 0.093 | 0.297*** | 0.311*** | 0.076 | 0.252** | 0.295** |
| | | 4.034 | 4.545 | 2.096 | 0.905 | 3.326 | 2.952 | 0.762 | 2.509 | 2.548 |
| | $IN^2$ | -1E-03*** | -2E-03*** | -2E-03** | -2E-04 | -1E-03** | -1E-03*** | -2E-05 | -8E-04 | -1E-03** |
| | | -3.364 | -3.929 | -2.083 | -0.392 | -2.596 | -2.687 | -0.042 | -1.672 | -2.043 |
| | $AdjR^2$ | 0.214 | 0.258 | 0.325 | 0.111 | 0.277 | 0.367 | 0.183 | 0.258 | 0.314 |
| Mkcp | NgR | 1.231 | 2.946 | -5.430 | -0.262 | -1.618 | -4.305 | 0.412 | 1.149 | -4.145 |
| | | 0.378 | 1.087 | -1.237 | -0.099 | -0.590 | -1.350 | 0.130 | 0.335 | -0.842 |
| | SdR | 1.633*** | -0.476 | -2.869** | 8.952*** | 11.750*** | 10.472* | 11.265*** | 12.790*** | 4.634 |
| | | 3.155 | -0.545 | -2.365 | 2.855 | 3.158 | 1.867 | 3.066 | 2.996 | 0.631 |
| | SkR | 0.013 | -0.469 | -3.945 | 1.213 | 1.809 | 3.174** | 0.400 | 1.479 | 4.863*** |
| | | 0.017 | -0.129 | -0.415 | 0.977 | 1.276 | 2.619 | 0.312 | 0.761 | 3.413 |
| | lnKm | -0.028 | -17.981** | -35.051*** | -2.680 | -14.210*** | -37.041*** | -5.108 | -16.264*** | -39.818*** |
| | | -0.006 | -2.463 | -3.407 | -0.416 | -3.497 | -6.623 | -0.753 | -3.593 | -6.545 |
| | IN | 0.043 | 0.132*** | 0.095* | 0.112*** | 0.136*** | 0.361*** | 0.109*** | 0.177*** | 0.177 |
| | | 0.815 | 3.942 | 1.799 | 3.112 | 3.995 | 2.933 | 2.744 | 3.527 | 1.318 |
| | $IN^2$ | -3E-05 | -1E-04*** | -1E-04* | -9E-05** | -1E-04*** | -3E-04*** | -8E-05** | -2E-04*** | -2E-04 |
| | | -0.423 | -3.381 | -1.863 | -2.658 | -3.680 | -2.880 | -2.263 | -3.247 | -1.330 |
| | $AdjR^2$ | 0.051 | 0.242 | 0.364 | 0.107 | 0.326 | 0.425 | 0.150 | 0.332 | 0.396 |
| Tidx | NgR | 3.501 | 2.304 | -6.829 | 1.556 | 0.046 | -5.083 | 2.076 | 1.398 | -11.946*** |
| | | 1.416 | 0.885 | -1.417 | 0.612 | 0.015 | -0.990 | 0.698 | 0.392 | -3.593 |
| | SdR | 1.534*** | 0.110 | -2.315* | 5.831** | 6.412 | 6.783 | 8.155** | 6.617 | -0.037 |
| | | 3.405 | 0.169 | -1.775 | 2.018 | 1.670 | 1.027 | 2.410 | 1.671 | -0.011 |
| | SkR | 0.062 | -1.070 | -3.840 | 0.115 | 0.354 | 0.978 | -0.848 | 0.967 | 0.214 |
| | | 0.095 | -0.910 | -0.397 | 0.103 | 0.239 | 0.541 | -0.632 | 0.600 | 0.091 |
| | lnKm | -0.891 | -12.580** | -30.170*** | -4.010 | -14.004*** | -25.296* | -6.727 | -15.440*** | -37.507*** |
| | | -0.225 | -2.258 | -2.753 | -0.676 | -3.663 | -1.912 | -1.022 | -4.233 | -8.712 |
| | IN | 1.869*** | 2.662*** | 2.493* | 2.540*** | 3.134*** | 4.029** | 2.509*** | 3.484*** | 3.562*** |
| | | 2.944 | 4.585 | 1.967 | 3.778 | 4.011 | 2.221 | 3.535 | 4.411 | 3.325 |
| | $IN^2$ | -6E-02* | -1E-01*** | -1E-01** | -7E-02*** | -1E-01*** | -2E-01** | -7E-02** | -1E-01*** | -1E-01*** |
| | | -1.812 | -3.370 | -2.134 | -2.955 | -3.429 | -2.217 | -2.531 | -3.571 | -3.383 |
| | $AdjR^2$ | 0.147 | 0.314 | 0.377 | 0.209 | 0.338 | 0.402 | 0.248 | 0.364 | 0.422 |

Note: This table presents the estimation results of the cross-market model by the quantile regression method. Net spillover index, calculated from variance decomposition, is used as dependent variables. IN is the measures of trade intensity. 'Trad', 'Tovr', 'Mkcp' and 'Tidx' indicate the total value of stock traded per GDP, the turnover ratio, market capitalisation per GDP and the trade intensity index are used as IN, respectively. $IN^2$ is the squared value of IN. Numbers in italics are t-statistics. Due to data limitation in some trade intensity measures (Table 2), 65 and 62 countries are utilised in the full and two post-crisis periods (post-2007 and post-2008), respectively. 0.1, 0.5 and 0.9 are three quantiles used in this regression. NgR is the strength of negative return, SdR is the standard deviation and SkR is the skewness of return. lnKm is the distance from the US.

Figure 1. The uni-directional spillover index




Note: This figure shows the change in the average of uni-directional spillover index, i.e. cross-variance shares, in the corresponding groups of markets – all (AL), advanced (AD), emerging (EM) and frontier (FR) markets. The time-series data of the index for each country is obtained by a cumulative-type moving-window forecasting of the VAR model and decomposition of its forecast errors as in (10). After generating 10 forecasts from the first 200 observations, the next 10 actual observations are added at each repetition of forecasting. Variance decomposition is used in calculation.