

Asymmetry in spillover effects: evidence for international stock index futures markets.

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Abstract:

The paper investigates the asymmetry in return and volatility spillovers across futures markets with non-overlapping stock exchange trading hours. The transmission of positive and negative return and volatility shocks is analysed for 104 channels of information conveyance identified by combining 9 developed and 11 emerging markets in markets pairs with non-overlapping trading hours. The asymmetric causality test is employed to daily stock index futures returns and volatilities for the period from 03 October 2010 to 03 October 2014. The paper sheds the light on the relatively little explored concept of asymmetry in return and volatility spillovers across markets, providing the novel evidence on stabilizing and destabilizing spillover effects.

Keywords: Asymmetric Spillover Effect; Return and Volatility Transmission; Stabilizing and Destabilizing Spillover Effect.

JEL Classification: G15; G11

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1. Introduction

The existing studies relying on the analysis of the dynamics, intensity and direction of return and volatility spillovers have been little focused so far on the issue of the transmission of positive and negative shocks across markets (e.g., Diebold & Yilmaz, 2009; Yarovaya, Brzeszczynski & Lau, 2016a). While the concept of asymmetric volatility has been examined by numerous papers (e.g., Nelson, 1991; Bekaert & Wu, 2000; Ferreira et al., 2007; Scharth & Medeiros, 2009; Jackwerth & Vilkov, 2014; Xiang & Zhu, 2014; Koulakiotis et al., 2015), the asymmetry in return and volatility transmission is not well explored, nor has it so far been investigated in the literature. A few papers, for example Koutmos and Booth (1995), Barun k et al. (2015), and Kundu and Sarkar (2016), analysed the transmission of positive and negative shocks from one market to another, shedding light on the concept of asymmetry in volatility spillovers. However, these papers provide evidence for only a small number of markets and their stock indices. The issues of information transmission across markets with non-overlapping stock exchange trading hours, i.e. same day effect and meteor shower effect, are not explored well in literature employing futures data (e.g., Pan & Hsueh, 1998; Wu et al., 2005; Gannon, 2005; Kao et al., 2015).

The results of the earlier studies, based on stock indices, should be interpreted with caution, because stock market indices are not easily investable assets, due to the higher cost of trading, potential trading and entry barriers (Barari, Lucey & Voronkova, 2008). Furthermore, Yarovaya, Brzeszczynski and Lau (2016a) argue that employing stock indices data only limits understanding of the practical implications of empirical results, because any trading strategy based on investing in various stock indices is an approximation that only makes sense in a theoretical context. Stock indices cannot be traded by investors as financial instruments;

therefore employing stock index futures data in analysis of return and volatility spillovers is more realistic.

This paper provides new evidence on asymmetry in spillover effects that has not been widely discussed in the literature. The opportunity to augment existing knowledge by investigating the asymmetry in return and volatility spillovers by utilizing both emerging and developed stock index futures data motivates this study. Thus, this paper contributes to the existing literature in the following ways.

First, our paper investigates the asymmetry in return and volatility spillovers across futures markets with non-overlapping stock exchange trading hours enhancing the literature on meteor shower effect (Engle, Ito & Lin, 1990). Due to the fact that this study employed alternative data from equity indices which, in practice, are not easily investable assets, the results have important practical implications, especially for investors that have diversification as a goal. The research by Clements et al. (2015) provided supporting evidence on the meteor shower hypothesis on futures markets, but analysed just the three largest markets, i.e. Japan, the US and Europe. There is a lack of international evidence on asymmetry in return and volatility spillovers across markets with non-overlapping trading hours. This paper analyses pairwise spillovers across 20 markets providing global evidence on the investigated phenomenon. The selected countries contain both emerging and developed markets from 4 geographical regions: Asia, the Americas, Europe and Africa.

Second, our study contributes to the literature by presenting empirical results from the investigation of the relatively unexplored concept of asymmetry in return and volatility spillovers across markets, presenting new evidence on stabilizing and destabilizing spillover effects. The paper goes beyond the investigation of the intensity of spillovers during periods of turmoil and tranquillity and also analyses the transmission of negative and positive returns and volatility shocks across markets with non-overlapping trading hours, providing the evidence

from stock index futures data. Since the issue of asymmetry in return and volatility transmission across stock index futures of the markets with non-overlapping stock exchange trading hours has not been sufficiently addressed yet in the literature, the study which analysed the transmission of positive and negative return and volatility across markets situated in different time zones can help to enhance the understanding of asymmetry in information transmission mechanism.

Third, this study provides novel empirical results utilizing the recently developed asymmetric causality test, as suggested by Hatemi-J (2012), which used bootstrap procedure to estimate critical values, and provides robust results on the ARCH effect¹, that has not yet been employed in an analysis of return and volatility transmission across stock index futures.

2. Literature review

2.1 Key concepts and definitions

The asymmetry in return and volatility spillovers may be hard to understand due to the fact that this phenomenon has not been well conceptualized yet in finance literature. Although the term “asymmetry” has been used in previous studies on equity markets behavior, the asymmetry in international spillover effect is different from those interpretations and requires further attention.

Since the work by Black (1976), Christie (1982) the presence of asymmetric volatility in financial markets has been well documented (e.g., Nelson, 1991; Bekaert & Wu, 2000; Ferreira, Menezes & Mendes, 2007; Xiang & Zhu, 2014). Although there is a long history of investigation of this phenomenon, “asymmetric volatility” and the associated term “asymmetry in volatility” has also been under consideration in the most recent literature. Albu, Lupu and Călin (2015)

¹ Because the descriptive statistics show the existence of heteroskedasticity in futures time-series, this study employs methodology that is robust under the ARCH effect. All results are available upon request.

defined asymmetric volatility, as a stylized fact that manifests itself when volatility is higher in market downswings than in market upturns. It relies on the empirical evidence that there is a negative correlation between returns and innovations in expected volatility (Dennis, Mayhew, & Stivers, 2006). In other words, by asymmetry in volatility, most studies originally assumed that volatility is higher during bear markets and lower during the bull markets (Talpsepp & Rieger, 2010)². Koulakiotis, Babalos and Papasyriopoulos (2015) further claimed that stock market volatility appears to rise more after a sharp fall in price (which is interpreted as bad news) than a respective rise in price (good news), which also describes the asymmetry in volatility. These two interpretations of asymmetry have been separated by El Babsiri and Zakoian (2001) into the terms “contemporaneous asymmetry”, i.e. different volatility processes for down and up moves in equity market returns, and “dynamic asymmetry”, i.e. asymmetric reactions of the volatilities to past negative and positive changes in returns (Palandri, 2015, p.486).

A similar understanding of asymmetry is evident in numerous studies analysing the impact of positive and negative news on stock market returns and the volatility of financial assets, where the term “asymmetric response” and “asymmetric effect” have also featured (e.g., Brzeszczyński, Gajdka & Kutan, 2015; Smales, 2015; Ning, Xu & Wirjanto, 2015; Bekaert, Engstrom & Ermolov, 2015). The literature typically suggests that a negative market shock has a stronger impact on returns and volatilities than does a positive shock of the same magnitude, which is manifested in asymmetry (e.g. Liu, Wong, An & Zhang, 2014; Smales, 2015). An alternative interpretation of asymmetry has been used in relation to another well-known, stylized fact, i.e. volatility clustering (Ning et al., 2015). Due to the fact that turbulent market periods tend to appear more frequently than tranquil market periods, Ning et al. (2015, p.62) claimed that high volatilities of returns tend to cluster more often than low volatilities of returns. He defines

² This phenomenon was also explained by Black (1976) and Christie (1982) which was also explained in literature as the leverage effect, i.e. meaning that a drop in the value of the stock increases financial leverage, which makes the stock riskier and increases its volatility (Talpsepp & Rieger, 2010).

asymmetric volatility clustering as “asymmetry in the frequency of clusters of high volatilities and low volatilities”.

This study investigates asymmetry in spillover effects across markets, therefore, none of the above definitions can be directly employed. Nevertheless, the interpretation of asymmetry in return and volatility spillovers used in this paper is based on several ideas presented in the literature. First, Kundu and Sarkar (2016, p. 298) argue that it is an established fact that the correlation between markets is higher during periods of high volatility than periods of low volatility (e.g., Longin & Solnik, 2001; Ang & Bekaert, 2002, Forbes & Rigobon, 2002). The spillover effect is a dynamic process and may vary with market conditions such as whether there is a ‘bull’ or ‘bear’ market. Second, Koutmos and Booth (1995) investigated the impact of good news (market advances) and bad news (market declines) on volatility transmission, and found that the volatility spillover effect is more pronounced when the news arriving from the last market to trade is bad, providing evidence of asymmetry. Third, the paper by Hatemi-J (2012) suggested that the transmission of positive and negative shocks may have different causal impacts.

In this paper asymmetry in spillovers is defined in the following way:

Asymmetry in spillover effect – is a phenomenon that occurs when the domestic financial market is more susceptible to negative (positive) than positive (negative) types of shocks transmitted from a foreign market.

It is important to clarify that asymmetry in volatility spillovers should be interpreted differently from asymmetry of return spillovers. ‘Positive’ and ‘negative’ volatility shocks indicate increases and decreases in the volatility of a market respectively, and do not necessarily provide information about the particular directions of return movements. While ‘good’ news causes growth of return, and ‘bad’ news causes decline in returns, regarding the volatility, both ‘good’ and ‘bad’ news may have a similar impact, i.e. an increase in market volatility. For

example, Chen and Ghysels (2011) found that moderately good news reduces volatility' while "both very good news (unusual high positive returns) and bad news (negative returns) increase volatility, with the latter having a more severe impact" (p.75). We define our volatility variable using the Rogers Satchell (RS) estimator, which relies on the information about the extent of the daily span between the highest and lowest price during the trading day and also the closing price (while the opening price does not matter in the RS measure because it naturally must lie between the high and low prices and what is only important in this volatility RS measure is the dynamics of the evolution of the daily price changes that leads to the final closing price within the bands determined by the high and low values for the day). Therefore, we understand the spillover in volatility between markets, following the Rogers Satchell (RS) estimator idea, as an effect of transmission of the magnitude of the RS values from one market on the magnitude of the RS values on another market.

In summary, information transmission mechanisms should be investigated separately for returns and for volatility. Referring to the study by Strohsal and Weber (2015), which analysed the dependency of intensity and direction of international volatility transmission on the degree of financial volatility of donor markets, the conclusion can be reached that the transmission of both positive and negative volatility shocks can be interpreted from two alternative perspectives. On the one hand, the volatility itself can be viewed as a sign of information flow, thus the increase in volatility of a donor's market generating intensive information flow, i.e. high spillover intensity, causing higher reactions in the recipient's market. For example, an increased volatility in China's market, increases the volatility of the South Korean market. On the other hand, volatility can be traditionally viewed as a reflection of uncertainty in the markets, thus the increasing volatility of a donor market increasing the uncertainty (noise) on the recipient market, leading to lower reactions in the target market. Consequently, the decline in volatility, i.e. negative volatility shock, can provide the signal to recipient market returns in the same way as an increase in volatility.

The paper by Segal, Shaliastovich and Yaron (2015) defined good and bad uncertainty, from the macroeconomic perspective, as the “variance associated with the respective positive and negative innovations of an underlying macroeconomic variable” (p.391). Alternatively this paper suggests definitions of positive and negative spillovers using financial markets perspective:

A. Spillover (transmission) of positive return/volatility shocks is effect when positive innovation, i.e. increase in returns/volatility, on one market causes positive innovation, i.e. increase in returns/volatility, on the other market.

B. Spillover (transmission) of negative return/volatility shocks is effect when negative innovation, i.e. decline in returns/volatility, on one market causes negative innovation, i.e. decline in returns/volatility, on the other market.

Although there is still very limited empirical evidence on asymmetry in return and volatility spillovers, several papers tested this phenomenon.

2.2 Cointegration

The literature on co-integration includes numerous papers that analysed long- and short-term relationships between financial markets (including Alagidede & Panagiotidis, 2009; Cajueiro, Gogas, & Tabak, 2009; Singh et al., 2010). The conventional analysis of equity markets co-integration is based on the idea that returns of co-integrated markets have a unit root. One of the most popular conventional approaches to testing markets on co-integration is to test series for one unit root by utilizing the augmented Dickey-Fuller (ADF) test suggested by Engle and Granger (1987). The Engle-Granger methodology for testing the co-integration hypothesis was employed by early studies (e.g., Bernard, 1991; Arshanapalli & Doukas, 1993; and Gallagher, 1995).

The Johansen co-integration test has been notably employed by Gilmore and McManus (2002) and Manning (2002). While a combination of the ADF and Johansen co-integration test is employed by Chen et al. (2002) to test co-integration hypothesis among six emerging stock markets from Latin America. Authors found that there were limited diversification benefits in

investing in various stock markets from Latin America, up until 1999, due to the commonalities of the business cycle and economic policies. However, the accuracy of the standard co-integration tests deteriorated once significant time-varying relationships and structural breaks were evident in the data generating process, resulting in the failure to reject the null hypothesis of no co-integration (e.g., Campos et al., 1996; Gregory & Hansen, 1996). The Johansen co-integration test has been employed as it takes into account regime-switch for regime switching in co-integrating relationships (e.g., Lucey & Voronkova, 2008; Kenourgios & Samitas, 2011; Kenourgios & Padhi, 2012),

Furthermore, Gregory and Hansen (1996) suggest that the standard co-integration tests may spuriously fail to reject the null hypothesis of no co-integration with the presence of structural changes. Their Monte Carlo simulation exercise further verifies that standard co-integration test loses validity and provides false conclusions when shifts in parameters take place. Gregory and Hansen (1996) discussed three alternative models to capture the changes in the co-integration vector. The first is the level shift model (or C model) that represents the change in the intercept at the time of the shift. The second model is level shift with trend (or C/T model) which allows the slope vector to shift as well. The last model allows for changes both in the intercept and in the slope of the co-integration vector (or C/S model). The co-integration test proposed by Gregory and Hansen (1996) allows one regime switch which is determined by the data. This methodology has been employed by Voronkova (2004) to test co-integration among developed European markets and the emerging Central European markets over a period from September, 1993 to April, 2002. The empirical results suggests that the increased integration between the emerging markets, i.e. the Czech Republic, Hungary, and Poland, and the developed markets, i.e. the UK, France, Germany, and the US, indicate diminution of the diversification benefits available in emerging markets in this region.

Finally, based on the framework of Gregory and Hansen (1996), a model that takes into account two structural shifts is developed by Hatemi-J (2008). His model considers the impact of two structural breaks on both the intercept and slopes (two regime shifts). The existence of structural breaks is a classical statistical problem which affects volatility and long-range dependence in stock returns (Andreou & Chysels, 2002). Besides cointegration literature, the test on structural breaks has been actively used in analyses of volatility spillovers, more specifically for investigation of the contagion phenomenon and for identification of the length of the financial crisis (e.g., Karanasos et al., 2014; Dimitriou, Kenourgios & Simos, 2013). A structural break, which can naturally be associated with the crisis shock, may change the stock market interdependencies during the crisis. Consequently, this limits the international portfolio

diversification benefits available during turmoil periods, when they are needed the most (Longin & Solnik, 2001).

2.3 Contagion

One of the central issues of international portfolio diversification are the increasing interdependencies of the financial markets during crisis periods. The presence of autoregressive conditional heteroskedasticity (ARCH effect) can have an impact on linear test statistics, thus Engle (1982) introduced ARCH class of models triggering the development of new procedures for modelling and forecasting time-varying financial market volatility (Bollerslev, 2008). The ARCH model by Engle (1982), and its generalisation by Bollerslev (1986), has been extended by many researchers and employed in analysis of stock market dependencies. The most influential early papers on ARCH class of models were summarised in Engle (1995). The ARCH family models have a dominant position in the analysis of international return and volatility transmissions across markets (e.g., Hamao, Masulis & Ng, 1990). The reason for the popularity of these models was their ability to capture the autoregressive conditional heteroskedasticity, which could not be captured by other famous methodologies, for example the VAR methodology employed by Eun and Shim (1989), Von Furstenberg and Joen (1989), Huang, Yang and Hu (2000), Sheng and Tu (2000), Masih and Masih (2001), and Climent and Meneu (2003).

There are several multivariate extensions of the univariate GARCH model, such as MGARCH, VEC and BEKK. Bollerslev, Engle and Wooldridge (1988) propose the general VEC (1, 1) model. Another extension is BEKK model was proposed by Engle and Kroner (1995) and it was related to earlier work on multivariate models by Baba, Engle, Kraft and Kroner (1991). However the main disadvantages of this model is the number of parameters to estimate. For example, in the BEKK (1, 1, 1) models, the number of parameters is $(5N+1)/2$, causing the problem of application to the big matrices. There are several restrictions proposed in literature to minimise the number of parameters in both VEC and BEKK models. However, these models are very rarely applied to the cases where the number of series is more than 3 or 4 (Bauwens et al., 2006).

For example, Li and Giles (2015) employed an asymmetric BEKK model to investigate volatility spillovers across the USA, Japan and the emerging stock markets of China, India, Indonesia, Malaysia, the Philippines and Thailand over the period from 1 January, 1993 to 31 December, 2012. The results show that the US stock market initiated unidirectional shock

spillovers to both the Japanese and the emerging stock markets, and these channels of information conveyance are robust in both the long and short term. Furthermore, the paper reports the volatility spillovers from Japan to the Asian emerging markets in both the long and short term. It is noteworthy that the linkages between the Japanese market and the emerging markets in the Asian region have become stronger during the past 5 years.

Engle (2002) introduced the dynamic conditional correlation (DCC) estimator which has several advantages over multivariate GARCH models. The first advantage is that it can be applied to large correlation matrices, which was inconvenient under the multivariate GARCH models because of the large number of parameters to be estimated. The number of parameters in the DCC method is not dependent on the number of the correlated series. Therefore, the DCC estimators keep the simplicity and flexibility of the univariate GARCH model. The DCC method can be ascertained using the original paper by Engle (2002). Cappiello et al. (2006), who proposed the asymmetric generalized dynamic conditional correlation (AG-DCC) model, developed it based on the seminal work of the DCC-GARCH model (Engle, 2002). The model takes into account conditional asymmetries in both volatilities and dynamic correlations, and it allows the modelling of time varying correlation during periods of negative shocks in a multivariate setting.

The Global Financial Crisis in 2007-2010 was the strongest global shock after the Great Depression and facilitated the new stream of academic literature investigating return and volatility spillovers around these crisis episodes (e.g., Luchtenberg & Vu, 2015). The recent Eurozone debt crisis in 2010 is also well documented in the contemporary literature on contagion (e.g., Petmezas & Santamaria, 2014). This strand of literature is very important because contagion across markets during periods of turmoil changes the benefits of international portfolio diversification available for investors. These crisis episodes are also significant in accordance to the analysed estimation period. Zhang et al. (2013) claim that after the world financial crisis, diminishing diversification benefits had become a long-running and world-wide phenomenon. However, according to the definition of contagion utilized in our study, the increased magnitude of return and volatility transmissions across international financial markets can offer further opportunities to forecast domestic market returns by using foreign information transmissions.

There is great diversity of methodologies, country selection, data frequency, and length of estimation periods employed within the literature. A study by Jung and Maderitsch (2014) investigates volatility spillovers across the US, Europe and Hong Kong using intra-daily data and confirms findings provided by Forbes and Rigoborn (2002). The authors claim that there is no

contagion across target markets. However, there is sound evidence of interdependence. The paper by Bekiros (2014) analyses the volatility spillovers between the US, the EU and the BRIC markets using the daily returns for the period from 5 January, 1999 to 28 February, 2011. The results demonstrate the intensification of linkages between BRIC and developed markets after the Global Financial Crisis. Similar results provided by Kenourgios, Samitas and Paltalidis (2011) used both a multivariate regime-switching Gaussian copula model and the asymmetric generalized dynamic conditional correlation (AG-DCC) approach to investigate non-linear correlation dynamics across the US, the UK and the BRIC stock markets during the period 1995–2006 which includes five crisis episodes. These findings are consistent with a recent paper by Syriopoulos, Makram and Boubaker (2015) which confirms strong spillovers from the US to BRICS stock markets providing evidence from the VAR (1) – GARCH (1, 1) framework. The empirical findings support a strong contagion effect from the crisis country to all others. Besides the contagion effect, Bekiros (2014) analysed the so-called “decoupling” phenomenon, which manifests itself in a growing influence of the emerging markets on developed markets, based on the assumption that the emerging markets become the major drivers of world economic growth as opposed to the US economy. However, the paper does not provide evidence on the decoupling hypothesis.

2.4 Inter-regional spillovers

The spillover effect has been analysed by many scholars with regard to their origins and the intensity of information transmission across markets from the both the same, and different, geographical regions. This branch of literature is particularly relevant to this research because the return and volatility spillovers across 21 markets, from 4 geographical regions, are analysed in this study. The regional perspective of contagion and spillover effect is critically important for portfolio managers and for policy makers due to the existence of various regional economic agreements (EU, ASEAN, BRICS, etc.). One of the central issues in this literature field is the existing channels of international information transmissions across the globe. The question why some countries are more susceptible to external shocks than others, and what the underlying reasons for this difference are, have become crucial to an understanding of the mechanisms of information transmission.

Bekaert et al. (2011) analysed information transmission across 55 equity markets, while 10 sectors provided evidence of contagion during the GFC. However, the dominant role of the US as the main source of contagion in global markets was not indicated. The strongest evidence

contagion was from domestic equity markets to individual domestic equity portfolios, while more financially integrated countries experienced less contagion from the US market. This led to rejection of the ‘globalization hypothesis’ (i.e. countries that are highly integrated globally, through trade and financial linkages, are more susceptible to the crisis shock). Instead, Bekaert et al (2011) found that portfolios in countries with weak macroeconomic fundamentals, i.e. high political risk, large current account deficits, large unemployment and high government budget deficits, were much more affected by the GFC and, in particular, by shock transmitted from the US., supporting the ‘wake-up call’ hypothesis. The “wake-up call hypothesis states that a crisis initially restricted to one market segment or country provides new information that may prompt investors to reassess the vulnerability of other market segments or countries, which spreads the crisis across markets and borders” (Bekaert et al., 2011, pp. 2-3).

Furthermore, Bekaert et al. (2011) argue that asymmetries in information may reduce capital flows across the borders and cause another well-established phenomenon called home bias. The home bias hypothesis is also known as the ‘home bias puzzle’, where investors holding a small amount of foreign stocks omit the potential diversification benefits available on international markets is analysed by numerous researchers (Cooper & Kaplanis, 1994; Kang & Stulz, 1997). One of the causes of information asymmetries in the global markets can be the fact that stock exchanges are situated in different regions and time-zones. Therefore, the home bias hypothesis is often analysed with related trading-place-bias hypothesis. For example, Kao, Hob and Fung (2015) claim that the trading-place-bias hypothesis implies that the price is influenced mainly by information linked to the trading hours or the location, while the home bias hypothesis assumes that information flows originate primarily in the home market, due to the fact that investors are better informed about their domestic firms and prefer to invest in securities traded on the home market. Also, in behavioural finance, the home bias puzzle is explained by investor behavioural bias referred to as “ambiguity aversion”, which describes irrational behaviour of investors’ decision making caused by avoidance of everything unknown and new.

One of the popular methods that allows the analysis of the partial effect of the markets on each other is the VAR model introduced by Sims (1980). Although a substantial quantity of available literature has investigated intra- and inter-regional information transmission, the existing empirical evidence is focused predominantly on the largest developed stock markets, and omits the emerging markets. The VAR method has been employed by Eun and Shim (1989) to investigate international information transmission across the developed stock markets of the US, the UK, Canada, France, Germany, Switzerland, Australia, Japan and Hong Kong.

Later, with the increased role of developing countries in the global economy, it became essential to include emerging markets in any analysis of information transmission mechanisms (e.g., Syriopoulos, 2007, Diebold & Yilmaz, 2009, 2012; Singh et al., 2010; Kumar, 2013; Cho, Hyde & Nguyen, 2014). Diebold and Yilmaz (2009) analysed return and volatility spillovers across seven developed and twelve emerging equity indices using a generalized VAR framework. Singh et al. (2010) investigated return and volatility spillovers across 15 markets from three geographical regions, Europe, Asia and North America, using the AR/VAR model to incorporate same day effect. Same day effect manifests itself in transmission of information across markets with non-overlapping trading hours within the same day, for example, from the stock market of Tokyo to the stock market of New-York. The authors utilized daily close-to-close and open-to-open returns from January, 2000 to February, 2008 and found that the market that opens prior to the current market has a strong influence on it. These findings are particularly significant for this research because it supports meteor shower effect and related same day effects that are discussed in subsequent subsections.

Ross (1989) showed that in absence of arbitrage, the volatility in asset returns depends upon the rate of information flow, which means that information transmitted from one market can generate an excess of volatility on another market. Engle, Ito and Lin (1990) incorporated the ARCH approach to an analysis of transmission of information contained in the first and second moments of stock market returns and the impact of those returns in other markets. Engle et al. (1990) used the real astronomical analogy with a meteor shower to describe the process of information transmission across global markets. Alternatively, the analogy with heat waves phenomenon has been used by Engle et al. (1990) to postulate that financial market volatility depends only on its own past shocks.

The phenomenon of the meteor shower is widely discussed in astrophysics and astronomy literature and comes in the form of a parallel stream of meteoroids entering the Earth's atmosphere at high speed. It is called a "shower" because, from the observers from Earth's viewpoint, it can appear that this stream of meteoroids has been generated from one point in sky. The heat waves phenomenon is a situation of abnormal increase in temperature in one particular country from the standard temperature normal for this area and season, lasting from a few days up to several weeks. Using these analogies, Engle et al. (1990) introduced the meteor shower hypothesis which assumes positive volatility spillover effects across markets, and alternatively the heat wave hypothesis which assumes that volatility has only country-specific autocorrelation. In other words, the meteor shower hypothesis suggests that a volatile day on one market is likely to be followed by a volatile day on another related market, while the heat wave

hypothesis suggests that a volatile day on one market is likely to be followed by a further volatile day on the same market (Ibrahim & Brzezczynski, 2009).

The meteor shower hypothesis is often tested in the context of so-called same day effect. The same day effect can be defined as spillover effect across geographically separated financial markets that trade sequentially (Andersen & Bollerslev, 1997). This effect has a central role in the analysis of inter-regional information transmission due to the fact that world stock exchanges operate in different time-zones and it is possible to investigate spillover across markets with non-overlapping trading hours. The main data, employed by researchers analysing same day effect, is open-to-close returns or a combination of open-to-close and close-to-open returns, representing daily and overnight returns (e.g., Hamao et al., 1990; Singh et al, 2010). Another group of studies used high-frequency return data to ex-post estimate the volatility of low-frequency returns (e.g., Melvin & Melvin, 2003; Koopman, Ooms, & Carnero, 2007; Andersen et al, 2006; Dimpfl & Jung, 2012), or intraday data various frequencies (e.g., Andersen & Bollerslev, 1997).

A study by Hamao et al. (1990) employed an MA(1)-GARCH(1,1)-M model to open-to-close and close-to-open returns to the stock markets of Tokyo, London and New York from April, 1985 to March, 1988 and found significant spillover effect across markets that open and close. Hamao et al. (1990) found evidence of spillover effect from the US and the UK to the stock market of Japan.

Golosnoy, Gribisch and Liesenfeld (2015) present a novel approach to the analysis of intra-day information transmissions in their study of the volatility spillovers within the US, German and Japanese stock markets which allows chronological ordering of overlapping and non-overlapping trading hours. They employed a sequential phase model accounting for the four distinct geographical intra-day trading periods: (1) the Germany-US trading overlap period; (2) the US-only trading period; (3) the Japan-only trading period; and (4) the Germany-only trading period (Golosnoy et al., 2015, p.97). Golosnoy et al. (2015) report intensification of inter-market linkages after a crisis across all three markets in the sample. The findings show that the strongest linkages are between the markets of the US and Germany. Furthermore, the results indicate the existence of meteor shower and heat wave effects before the GFC, while after the crisis the meteor shower effect becomes more pronounced.

Maderitsch (2015) analysed return spillovers in Hong Kong, the US and Europe over the period 2000 to 2011. The study employed the Granger causality test to non-overlapped intraday equity index returns. The study provided evidence of both positive and negative spillovers across markets. Particularly, the positive spillovers are found from Hong Kong and the US to Europe

and from Europe to the US during periods of high volatility, while negative spillovers are found from the US to Hong Kong. The author explained the sign of spillovers using a rational explanation, i.e. difficulties in assessing the information content, and psychological explanations, i.e. traders might underreact at market opening. However, the concepts of positive and negative spillovers are not well-defined in this paper and require further attention.

2.5 Asymmetry in volatility spillovers

Although asymmetry in volatility has been actively tested and is referenced in finance literature (e.g., Albu et al, 2015; Koulakiotis et al, 2015; Bekaert et al., 2015, among others), the discussion of asymmetric effect in return and volatility spillovers is very limited. One of the first attempts to investigate asymmetry in volatility transmission was performed by Bae and Karolyi (1994) and Koutmos and Booth (1995). Koutmos and Booth (1995) employed the multivariate EGARCH to investigate price and volatility spillovers across the equity markets of New York, Tokyo and London. The study utilized the daily open-to-close returns for the aggregate stock price indices, i.e. the S&P 500 for the USA, the FTSE-100 for the UK, and the Nikkei 225 Stock Index for Japan, for the period September, 1986 to December, 1993. The findings show the following channels of transmission: i) the price spillovers from New York to Tokyo and London, and from Tokyo to London; ii) volatility spillovers from New York to London and Tokyo, from London to New York and Tokyo, and from Tokyo to London and New York. Furthermore, the empirical results suggest that the impact of negative innovation is stronger than the impact of positive innovations for all channels of transmission, which confirms the existence of asymmetry in volatility transmission mechanisms.

The paper by Baruník, Kočenda, and Vácha (2015) examined the asymmetries in volatility spillovers that emerge due to bad and good volatility. The authors hypothesized that volatility spillovers might significantly differ depending on the qualitative nature of the preceding shock. Baruník et al. (2015) employed a new measure of volatility, so-called realized

semivariance (Barndorff-Nielsen, Kinnebrock & Shephard, 2010), which measures the variation of the change in the asset price and reflects the direction of the change. Furthermore, the authors employed the Diebold and Yilmaz (2012) spillover index, i.e. directional and total, to test whether positive and negative spillovers are of the same magnitude. More specifically, the negative realized semivariance comes from the negative returns, while the positive realized semivariance comes from positive returns. Therefore, employing both positive and negative realized semivariance allows the testing of the asymmetry in volatility transmission in equity markets.

However, Baruník et al. (2015) tested asymmetry in volatility spillovers utilizing daily data covering 21 U.S. stocks from seven sectors, rather than equity indices. They found asymmetric connectedness of markets at the disaggregated level, reporting that positive and negative spillovers are of different magnitudes in all sectors. Another study by Kundu and Sarkar (2016) analysed daily stock returns data from two developed markets, i.e. the US and the UK, and four emerging countries, i.e. BRIC (Brazil, Russia, India and China), to investigate asymmetry in information transmission mechanisms during periods of turmoil and turbulence, using daily data from January, 2000 to December, 2012. They proposed that STVAR-BTGARCH-M allows the smooth transition of behaviour to switch from one market condition to another. The empirical results show the strong connectedness between the developed markets of the US and the UK during both up and down market conditions. However, the signs of the spillover effect may vary. The evidence for the emerging markets is mixed, for some market pairs spillovers are negative, for others the combinations of market spillover effect is positive. For only one emerging market, i.e. China, the findings demonstrated persistence of only negative spillover effects to other markets. Kundu and Sarkar (2016) found strong evidence of asymmetric spillover effects among international equity markets in both periods of stability and crisis.

Understanding of asymmetry in spillover effect has important implications to international portfolio diversification. The study by Yarovaya and Lau (2016) examined transmission of negative and positive return shocks from UK stock market to BRICS and MIST (Mexico, Indonesia, South Korea and Turkey) markets. The paper shows that increased intensity of transmission of negative return shocks during the crisis period can be associated with contagion phenomenon, limiting the benefits of international diversification across markets during financial turmoil. However, transmission of positive return innovations indicates interconnectedness rather than contagion. Thus Yarovaya and Lau (2016) report that market pairs of UK–Brazil, UK–South Africa and UK–Mexico demonstrated increase in causal linkages during crisis period, which can be interpreted as supporting evidence of contagion effect, while there is no evidence of contagion found for the UK–India, UK–Indonesia and UK–South Korea market pairing. Besides the analysis of return spillovers, another recent paper by Yarovaya et al. (2016b) presents the evidence for asymmetry in volatility spillovers across Asian futures markets. Authors found that some markets play a destabilizing role while other countries have a stabilizing effect on other markets in Asia. The study considered asymmetry in spillovers across 6 Asian markets only, therefore there is a need of study providing global evidence. Thus, the asymmetry in spillover effect, and particularly, i.e. stabilizing role of volatility spillovers, are further explored in this paper contributing to existing debate in the spillovers literature.

3. Methodology

3.1 Data

There are 20 countries selected for investigation in this study. The data sample contains 9 developed and 11 emerging markets from four geographical regions: Europe (Germany, France, Spain, Switzerland, Russia, Hungary and Turkey)³, Africa (South Africa), Asia (Hong Kong, Japan, Singapore, South Korea, China, India, Taiwan, and Malaysia) and the Americas (Canada, USA, Mexico and Brazil). In this study, we expand paper by Yarovaya et al. (2016a) that employed Diebold and Yilmaz (2012) methodology to the similar data set, however didn't covered the phenomenon of asymmetry in information transmission between markets with non-overlapping trading hours. The paper utilizes stock index futures data to fill the gap in literature, hence the trading hours of futures are considered to identify market pairs with non-overlapping trading hours taking into account difference in time-zone and DST policies. Table 1 demonstrates that using the data set of 9 developed and 11 emerging markets it is possible to analyse 104 channels of return and volatility transmission avoiding overlap in trading hours.

[Table 1 around here]

For example, the stock market in Germany opens when stock market in Taiwan is closed. Therefore the pair Germany–Taiwan provides two routes of information transmission for analysis; that is, from Taiwan to Germany and the reverse direction from Germany to Taiwan, as is demonstrated by Figure 1 below.

[Figure 1 around here]

³ The United Kingdom is not considered in the sample in this study, because the futures trading hours are overlapping with all other markets in the sample.

Therefore the channels of inter-regional return and volatility spillovers across sequentially opening and closing markets are between Europe and Asia and between Asia and Americas. This is because European and Americans markets have an overlap in trading times.

Thus, 20 markets were selected for investigation of asymmetry in inter-regional return and volatility transmission across futures markets, with non-overlapped trading times for the period from 03 October 2010⁴ until 03 October 2014. The daily opening, closing, high and low prices of stock index futures are obtained from the Bloomberg database. Due to the finite lifetime of a futures contract, both returns and volatility data are transformed into a continuous time series using roll timing method, which determines when the near contract is dropped and replaced by the next one (Masteika & Rutkauskas, 2012, p.921). All returns are calculated as a difference between natural logarithm of closing price and natural logarithm of opening price. The volatilities are calculated using the Rogers and Satchell (1991) range volatility estimator:

$$\delta_{RS}^2 = h_t(h_t - c_t) + l_t \times (l_t - c_t) \quad (1)$$

where: h_t - the normalized high price; l_t - the normalized low price; c_t - the normalized closing price on date t . The descriptive statistics for both returns and volatilities is available upon request.

3.2 Research hypotheses

In order to investigate whether asymmetric patterns exist in return and volatility spillovers across futures markets with non-overlapped stock exchange trading hours, the following research hypotheses are tested:

Hypothesis 1: *The transmission of negative return shocks across markets with non-overlapping trading hours is more pronounced than the transmission of positive shocks.*

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

This hypothesis presumes that domestic market returns are more susceptible to negative than positive types of shocks transmitted from a foreign market. The verification of this hypothesis provides supporting evidence to the asymmetry in return spillover effect.

Hypothesis 2: *The transmission of positive return shocks across markets with non-overlapping trading hours is more pronounced than the transmission of negative shocks.*

This hypothesis suggests that domestic market returns are more susceptible to positive than negative type of shocks transmitted from a foreign market. The verification of this hypothesis provides supporting evidence for asymmetry in return spillover effect.

Simultaneous rejection of the H1 and H2 indicates the absence of asymmetry in return spillovers for the analysed market.

Hypothesis 3: *The transmission of negative volatility shocks across markets with non-overlapping trading hours is more pronounced than the transmission of positive shocks.*

This hypothesis assumes that domestic market volatility is more sensitive to negative than positive types of shocks transmitted from a foreign market. The verification of this hypothesis provides supporting evidence for asymmetry in the volatility spillover effect.

Hypothesis 4: *The transmission of positive volatility shocks across markets with non-overlapped trading hours is more pronounced than the transmission of negative shocks.*

This hypothesis suggests that domestic market volatility is more susceptible to positive than negative types of shocks transmitted from a foreign market. The verification of this hypothesis provides supporting evidence for the asymmetry in volatility spillover effect.

Simultaneous rejection of the H3 and H4 indicates the absence of asymmetry in volatility spillovers for the analysed market.

3.3 Econometric framework

In order to test the asymmetry in return and volatility spillovers, this paper employs the asymmetric causality test proposed by Hatemi-J (2012). The idea of transforming the data into both cumulative positive and negative innovations was originated by Granger and Yoon (2002), who used this approach to test time-series for cointegration. Subsequently, Hatemi-J (2012) adopted this idea to investigate the causal linkages between positive and negative innovations between two variables. The asymmetric causality with bootstrap simulation approach for calculating of critical values proposed by Hatemi-J (2012) was selected for this research, due to the fact that it is able to capture the asymmetry in information transmission mechanism, and also it is robust to the existence of ARCH effect (e.g., Hacker & Hatemi-J, 2012). Following Hatemi-J (2012) the employed approach is discussed below⁵.

Assume that two integrated variables y_{1t} and y_{2t} are described by the following random walk processes:

$$y_{1t} = y_{1t-1} + \theta_{1t} = y_{1,0} + \sum_{i=1}^t \theta_{1i}^+ + \sum_{i=1}^t \theta_{1i}^-, \quad (2)$$

and similarly

$$y_{2t} = y_{2t-1} + \theta_{2t} = y_{2,0} + \sum_{i=1}^t \theta_{2i}^+ + \sum_{i=1}^t \theta_{2i}^-, \quad (3)$$

The cumulative sums of positive and negative shocks of each underlying variables can be defined as follows:

$$y_{1t}^+ = \sum_{i=1}^t \Delta\theta_{1i}^+, y_{1t}^- = \sum_{i=1}^t \Delta\theta_{1i}^-, \quad y_{2t}^+ = \sum_{i=1}^t \Delta\theta_{2i}^+, \quad y_{2t}^- = \sum_{i=1}^t \Delta\theta_{2i}^-, \quad (4)$$

where positive and negative shocks are defined as: $\theta_{1t}^+ = \max(\Delta\theta_{1i}, 0)$; $\theta_{2t}^+ = \max(\Delta\theta_{2i}, 0)$; $\theta_{1t}^- = \min(\Delta\theta_{1i}, 0)$, and $\theta_{2t}^- = \min(\Delta\theta_{2i}, 0)$.

⁵ The paper used GAUSS coding provided by Hatemi-J (2012) to conduct asymmetric causality test.

To test the causalities between these components vector autoregressive model of order p , VAR (p) is used:

$$y_t^+ = v + A_1 y_{t-1}^+ + \dots + A_p y_{t-p}^+ + u_t^+, \quad (5)$$

where $y_t^+ = (y_{1t}^+, y_{2t}^+)$ is the 2×1 vector of the variables, v is the 2×1 vector of intercepts, and u_t^+ is a 2×1 vector of error terms (corresponding to each of the variables representing the cumulative sum of positive shocks); A_j is a 2×1 matrix of parameters for lag order γ ($\gamma = 1, \dots, p$). The information criterion suggested by Hatemi-J (2003) is used to select the optimal lag order (p):

$$HJC = \ln(|\hat{\Omega}_j|) + j \left(\frac{n^2 \ln T + 2n^2 \ln(\ln T)}{2T} \right), \quad (6)$$

where $j = 0, \dots, p$; $|\hat{\Omega}_j|$ is the determinant of the estimated variance-covariance matrix of the error terms in the VAR model based on the lag order j , n is the number of equations in the VAR model and T is the number of observations.

This information criterion was tested by Hatemi-J (2008). The simulation experiments confirmed the robustness of this criterion to ARCH effect, which is important for this paper due to the existence of heteroskedasticity in the data.

The next step of the analysis is to test the Null Hypothesis that k th element of y_t^+ does not Granger-cause the ω th element of y_t^+ using the Wald test methodology. Furthermore, Hatemi-J (2012) employed a bootstrap algorithm with leverage correction to calculate the critical values for the asymmetric causality test in order to remedy the heteroskedasticity problem. The details of the Wald test methodology and the bootstrap procedure discussed in depth by Hacker and Hatemi-J (2012), Hatemi-J (2012).

4. Empirical results

Due to the fact that an asymmetric causality test allows investigation of the impact of positive and negative shocks separately, the test has been employed twice for each combination of markets, leading to 208 total estimations. Furthermore, the asymmetry in causal linkages has been analysed for both return and volatilities; therefore, the test was conducted on 416 cases overall. Eight markets from Asia region were investigated as recipients of the information flows originated from positive and negative innovations in return on relative foreign markets, i.e. from Europe and Africa and the Americas regions. The asymmetric causality test was conducted on 52 pairs of markets for both positive and negative type of shocks, thus 104 Null Hypotheses of absence of causal linkages between markets analysed for this region. Overall, the Null Hypothesis was rejected for 49 cases (i.e. 47%) indicating presence of inter-regional causal linkages at different levels of significance. Hence, the evidence of causality was found for 23 out of 49 cases (i.e. 46.9%) at the 1% significance level, 13 cases (i.e. 26.5%) at the 5% significance level, and for 13 cases (i.e. 26.5%) at the 10% significance level. However, the evidence of causality varies across markets, which indicates that some Asian markets are more susceptible to foreign shocks than others.

The results are summarized in Table 2 below.

[Table 2 around here]

The evidence for China demonstrates that futures returns are not affected by negative or positive shocks transmitted from the futures markets of Turkey, Canada, USA, Mexico and Brazil. The relative independence of the Chinese markets from foreign shocks can be explained from two perspectives. First, due to the fact that stock index futures are comparatively new financial instrument for this market and, as has been mentioned before, stock index futures were introduced in April 2010, and the degree of development and financial integration of this asset

may be lower than in the Asian markets⁶. Second, the restricted access to this market for foreign investors, due to its unique institutional arrangement, can cause the isolation of financial futures' markets. In regard to this stance, the Chinese market is potentially attractive from the perspective of international diversification. However, these diversification benefits are not fully available to foreign investors due to the lack of market openness in China. These results also support the position held by Aityan et al. (2010), who indicate that China plays one of the leading roles in the global economy and is relatively isolated from external shocks.

In similar way, the asymmetric causality test was employed to volatility data in order to investigate the impact of transmission of the information flows originated from positive and negative innovations on volatility of Asian markets. Table 3 summarizes the results for volatility:

[Table 3 around here]

Amongst the 104 Null Hypotheses tested in this paper the evidence of causality was found for 36 cases (i.e. 34.6%) of the sample, which is lower than evidence obtained for returns (47%). Thus the intensity of volatility spillovers is lower than return spillovers. More specifically, the Null Hypothesis was rejected for 13 out of 36 cases (i.e. 36.1%) at the 1% significance level, for 16 cases (i.e. 44.4 %) at the 5% significance level, and for 7 cases (i.e. 19.4 %) at the 10% significance level. While the results obtained for returns show that China is not susceptible from any type of shocks originated in the foreign market, Table 3 demonstrates causality between negative innovation on Mexican market volatility and negative innovations on Chinese market volatility, because the Null Hypothesis is rejected at 10% significance level.

Eight markets from Europe and Africa time-zone were considered as a recipient of the information flows originated from positive and negative innovations in return on relative markets from Asian region. Table 4 shows that for the European and South African futures returns the

⁶ The first stock index futures contracts traded in China was IFBK10 (04/16/10-05/21/10), in Hong Kong it was HIJ92 (04/01/92-04/29/92), in Taiwan it was FTU98 (07/21/98-09/17/98), in Singapore it was QZV98 (09/07/98-10/30/98), in South Korea it was KMM96 (05/03/96-06/13/96) and in Japan it was NKZ88 (09/05/88-12/08/88).

Null Hypothesis was rejected for 32 out of 44 cases (i.e. 72.7%), which is higher than for Asian region (i.e. 47%). The evidence of causality was found for 28 out of 32 cases (i.e. 87.5%) at the 1% significance level, 2 cases (i.e. 6.25%) at the 5% significance level, and also for 2 cases (i.e. 6.25%) at the 10% significance level. Therefore, the significance of the results is also higher for this region rather than for Asia. Furthermore, in contrast to Asian markets, none of the target markets from Europe and Africa are fully independent from external shocks.

[Table 4 around here]

In a similar way, Table 5 summarizes the empirical results for volatility. For the European and South African futures volatility the Null Hypothesis was rejected for 35 out of 44 cases (i.e. 79.5%), which is higher than for returns (i.e. 72.7%), and higher than for volatilities of Asian region (34.6%). Therefore, while evidence for Asia supports that intensity of return spillovers is higher than volatility spillovers, the results for Europe and Africa show reverse pattern.

[Table 5 around here]

The evidence of volatility transmission for developed European markets confirms that Germany, France, Spain and Switzerland are susceptible from both negative and positive volatility shocks originated on the market of Taiwan. The stabilising role of transmission of negative volatility shocks is evident for Singapore -Turkey channel, where the hypothesis of no causalities is rejected at 1% level for the negative innovations, but could not be rejected for positive.

Due to the fact that markets in the Americas region have no overlap in trading hours with Asian markets, it has been possible to investigate multiple channels of return and volatility transmission across the majority of market pairs, making the empirical results especially fruitful. The results for returns are summarised in Table 6 below.

[Table 6 around here]

The Null hypothesis has been rejected for 50 out of 60 cases (i.e. 83.3%), which is higher than for Asian (i.e. 47%) and the European and Africa (i.e. 72.7%) regions. The evidence of causality was found for 38 out of 50 cases (i.e. 76%) at the 1% significance level, 7 cases (i.e. 14%) at the 5% significance level, and for 5 cases (i.e. 10%) at the 10% significance level. Similar to Europe and Africa, and contrary to Asia, none of the markets of Canada, USA, Mexico and Brazil are isolated from external shocks and susceptible to the majority of Asian markets in the sample. The results for volatility presented in Table 7:

[Table 7 around here]

The evidence of causality among futures volatility was found for 32 out of 49 cases (i.e. 65.3%) at the 1% significance level, 11 cases (i.e. 22.4%) at the 5% significance level, and also for 6 cases (i.e. 12.2%) at the 10% significance level, which shows that the significance of the results is generally lower for volatility than for returns.

5. Discussion

We found that the asymmetry in return and volatility spillovers across stock index futures is evident for some market combinations in the sample, but not for all of them. For example, Hypothesis 1 (*i.e. the transmission of negative return shocks across markets with non-overlapped trading hours is more pronounced than the transmission of positive shocks*) is rejected for a market if, for the majority of cases, the transmission of negative shocks is confirmed. Due to the fact that the basic Null Hypotheses of absence of causalities has been tested 416 times in the results achieved is massive and not all of them are discussed within this paper. The findings are summarized in Table 8.

[Table 8 around here]

Despite the simultaneous rejection of H1 and H2 for return, and H3 and H4 for volatility indicates the absence of asymmetry in spillover effect, this situation does not necessarily mean the absence of causal linkages. For instance, while for Japan and Hong Kong, results demonstrate clear evidence of asymmetry in causalities between returns, for Singapore it was found that returns are susceptible to transmission of both positive and negative types of shock. As such, both H1 and H2 are rejected. The evidence of asymmetry does not characterize the market that has very strong causalities with others. For the Hong Kong market, asymmetry in spillover was found due to the fact the Hong Kong is susceptible only from the one type of shocks transmitted from Brazil, and independent of both types of shock from any other markets. The evidence, overall, suggests that Hong Kong is a market in the Asian region that is comparatively isolated from foreign shocks, as are those of China and India.

Therefore, asymmetry in return transmission is evident for the futures markets of Hong Kong, Japan, Malaysia, Taiwan, Turkey and Canada, where markets are more susceptible to transmission of negative shocks, and for the markets of Spain and the US, where spillovers of positive shocks are more pronounced. The results show that although there are mutual causal linkages existing between markets with non-overlapping trading hours, asymmetry of return spillovers are identified for 8 out of 20 markets in the sample. The asymmetry in volatility spillovers is found for 10 out of 20 markets. In Hong Kong, Japan, Singapore, Korea, Malaysia, Taiwan, Canada and Brazil the conveyance of positive volatility shocks, i.e. destabilizing volatility spillovers, dominates, while the evidence for China and Russia suggested the reverse pattern, i.e. stabilizing volatility spillovers. Overall, the results show that transmission of negative return shock and positive volatility shocks dominate in this observation sample. Summarizing the results for different combinations of markets, i.e. developed-developed, emerging-emerging, emerging-developed and developed-emerging (where the former market is a recipient of information) it was found that the strongest asymmetry is for market pairs where the

recipient is an emerging market. There is no evidence of asymmetry for developed-developed and developed-emerging market combinations.

6. Conclusions

Our findings contribute to the existing literature through analysing the transmission of the negative and positive return and volatility shocks across markets with non-overlapping trading hours. The concept of asymmetry in return and volatility spillovers across markets has been relatively little explored (Koutmos & Booth, 1995; Barun k et al., 2015; Segal et al., 2015; Kundu & Sarkar, 2016; Yarovaya et al., 2016b). This research augments existing knowledge and provides recent international evidence on asymmetry in spillover effects by utilizing stock index futures data. The findings indicate asymmetry in spillovers that is consistent with results from (Kundu & Sarkar, 2016), where returns are more sensitive to negative shocks (e.g. Koutmos & Booth, 1995), and volatility to positive shocks. However, although volatility spillovers are traditionally viewed as destabilizing forces only, asymmetric tests show that decreases in volatility on one market can cause decreases in volatility in other markets. The transmission of negative volatility shocks may play a stabilizing role in the region. The results provide the new evidence of both stabilizing and destabilizing spillover effects across markets.

We identified strong asymmetry in spillovers for market pairs where the recipient is an emerging market, while there is no evidence of asymmetry for developed-developed and developed-emerging market combinations. The analysis carried out provided an original contribution to the literature and interesting, due to the employment of futures data, recent methodology and a broader country panel. We also focused on answering the question of ‘how’ the financial markets are interlinked, providing the novel evidence on asymmetry of spillovers. However, the central question of future research could well be ‘why’ returns and volatility spillovers follow the patterns identified and documented in our study.

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Table 1. Markets pairs with non-overlapping trading hours.

Country	Futures trading hours (GMT)	Futures trading hours during DST	Combined with	Number of combinations
Asia				
Hong Kong	01:15-04:00; 05:00-08:15	01:15-04:00; 05:00-08:15	TUR, CAN, USA, MEX, BRA	5
Japan	00:00-6:15	00:00-06:15	ESP, RUS, HUN, TUR, ZAF, CAN, USA, MEX, BRA	9
Singapore	00:30-09:15	00:30-09:15	TUR, CAN, USA, MEX, BRA	5
China	01:15-03:30; 05:00-07:15	01:15-03:30; 05:00-07:15	TUR, CAN, USA, MEX, BRA	5
South Korea	00:00-06:15	00:00-06:15	ESP, RUS, HUN, TUR, ZAF, CAN, USA, MEX, BRA	9
Malaysia	00:45-03:45; 06:30-08:15	00:45-03:45; 06:30-08:15	TUR, CAN, USA, MEX, BRA	5
Taiwan	00:45-05:45	00:45-05:45	GER, FRA, ESP, SUI, RUS, HUN, TUR, ZAF, CAN, USA, MEX, BRA	12
India	03:30-12:45	03:30-12:45	CAN BRA	2
Europe and South Africa				
Germany	06:50-21:00	05:50-20:00	TWN (t+1)	1
France	07:00-21:00	06:00-20:00	TWN (t+1)	1
Spain	08:00-19:00	07:00-18:00	JPN (t+1), KOR (t+1), TWN (t+1)	3
Switzerland	06:50-21:00	05:50-20:00	TWN (t+1)	1
Russia	07:00-15:45; 16:00-20:50	07:00-15:45; 16:00-20:50	JPN (t+1), KOR (t+1), TWN (t+1)	3
Hungary	08:02-16:00	07:02-15:00	JPN (t+1), KOR (t+1), TWN (t+1)	3
Turkey	11:55-15:45	10:55-14:45	HKG(t+1), JPN(t+1), SGP(t+1), CHN(t+1), KOR(t+1), MYS(t+1), TWN(t+1)	7
South Africa	06:30-15:30	06:30-15:30	JPN, KOR, TWN	3
Americas				
Canada	11:00-21:15	10:00-20:15	HKG(t+1), JPN(t+1), SGP(t+1), CHN(t+1), KOR(t+1), MYS(t+1), TWN(t+1), IND(t+1)	8
USA	13:30-20:15	12:30-19:15	HKG(t+1), JPN(t+1), SGP(t+1), CHN(t+1), KOR(t+1), MYS(t+1), TWN(t+1)	7
Mexico	13:30-21:00	12:30-20:00	HKG(t+1), JPN(t+1), SGP(t+1), CHN(t+1), KOR(t+1), MYS(t+1), TWN(t+1)	7
Brazil	11:00-19:55	10:00-18:55	HKG(t+1), JPN(t+1), SGP(t+1), CHN(t+1), KOR(t+1), MYS(t+1), TWN(t+1), IND(t+1)	8
Total:				104

Note: notation (t+1) represents one day time lead in comparison to the country in the first column.

Table 2. The Asymmetric Causality Test Results for Returns, Asia.

Null Hypothesis	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Conclusion
Hong Kong as a recipient					
TUR + \nrightarrow HKG +	0.872	9.275	5.743	4.486	TUR + \nrightarrow HKG +
TUR - \nrightarrow HKG -	2.106	8.865	5.884	4.455	TUR - \nrightarrow HKG -
CAN + \nrightarrow HKG +	3.999	8.739	5.765	4.312	CAN + \nrightarrow HKG +
CAN - \nrightarrow HKG -	2.584	9.041	6.169	4.861	CAN - \nrightarrow HKG -
USA + \nrightarrow HKG +	4.110	11.432	8.154	6.407	USA + \nrightarrow HKG +
USA - \nrightarrow HKG -	4.862	12.401	7.993	6.256	USA - \nrightarrow HKG -
MEX + \nrightarrow HKG +	1.628	9.623	6.238	4.571	MEX + \nrightarrow HKG +
MEX - \nrightarrow HKG -	3.994	9.224	6.062	4.607	MEX - \nrightarrow HKG -
BRA + \nrightarrow HKG +	1.954	9.001	6.089	4.540	BRA + \nrightarrow HKG +
BRA - \nrightarrow HKG -	5.715*	9.071	5.689	4.433	BRA - \Rightarrow HKG -
Japan as a recipient					
ESP + \nrightarrow JPN +	0.935	10.957	6.488	4.673	ESP + \nrightarrow JPN +
ESP - \nrightarrow JPN -	5.559*	8.946	6.034	4.899	ESP - \Rightarrow JPN -
RUS + \nrightarrow JPN +	3.186	9.862	5.472	4.394	RUS + \nrightarrow JPN +
RUS - \nrightarrow JPN -	2.820	9.023	5.711	4.318	RUS - \nrightarrow JPN -
HUN + \nrightarrow JPN +	0.007	9.047	6.088	4.717	HUN + \nrightarrow JPN +
HUN - \nrightarrow JPN -	1.351	8.935	6.090	4.575	HUN - \nrightarrow JPN -
TUR + \nrightarrow JPN +	2.098	10.282	6.412	4.797	TUR + \nrightarrow JPN +
TUR - \nrightarrow JPN -	5.630*	9.094	6.115	4.751	TUR - \Rightarrow JPN -
ZAF + \nrightarrow JPN +	0.633	9.355	5.807	4.440	ZAF + \nrightarrow JPN +
ZAF - \nrightarrow JPN -	0.981	8.906	6.213	4.426	ZAF - \nrightarrow JPN -
CAN + \nrightarrow JPN +	0.066	10.346	6.343	4.590	CAN + \nrightarrow JPN +
CAN - \nrightarrow JPN -	8.851**	10.548	5.886	4.384	CAN - \Rightarrow JPN -
USA + \nrightarrow JPN +	4.427	12.736	7.864	6.579	USA + \nrightarrow JPN +
USA - \nrightarrow JPN -	4.555	13.856	9.296	7.658	USA - \nrightarrow JPN -
MEX + \nrightarrow JPN +	2.456	11.792	6.109	4.710	MEX + \nrightarrow JPN +
MEX - \nrightarrow JPN -	9.545**	10.567	6.742	5.001	MEX - \Rightarrow JPN -
BRA + \nrightarrow JPN +	3.543	9.453	6.263	4.719	BRA + \nrightarrow JPN +
BRA - \nrightarrow JPN -	7.375**	10.196	6.434	4.991	BRA - \Rightarrow JPN -
Singapore as a recipient					
TUR + \nrightarrow SGP +	5.759*	8.183	5.897	4.666	TUR + \Rightarrow SGP +
TUR - \nrightarrow SGP -	5.466*	8.947	5.550	4.247	TUR - \Rightarrow SGP -
CAN + \nrightarrow SGP +	1.000	8.733	5.783	4.505	CAN + \nrightarrow SGP +
CAN - \nrightarrow SGP -	0.852	9.586	6.361	4.766	CAN - \nrightarrow SGP -
USA + \nrightarrow SGP +	8.234**	12.837	7.582	6.010	USA + \Rightarrow SGP +
USA - \nrightarrow SGP -	12.566***	10.329	7.661	6.160	USA - \Rightarrow SGP -
MEX + \nrightarrow SGP +	8.981***	8.508	5.476	4.243	MEX + \Rightarrow SGP +
MEX - \nrightarrow SGP -	26.351***	11.478	8.082	6.559	MEX - \Rightarrow SGP -
BRA + \nrightarrow SGP +	8.298**	9.977	5.947	4.484	BRA + \Rightarrow SGP +
BRA - \nrightarrow SGP -	19.735***	11.223	7.621	6.066	BRA - \Rightarrow SGP -
China as a recipient					
TUR + \nrightarrow CHN +	1.223	10.003	6.235	4.486	TUR + \nrightarrow CHN +
TUR - \nrightarrow CHN -	0.422	10.704	6.306	4.829	TUR - \nrightarrow CHN -
CAN + \nrightarrow CHN +	0.957	9.680	5.673	4.275	CAN + \nrightarrow CHN +
CAN - \nrightarrow CHN -	0.201	8.106	5.492	4.334	CAN - \nrightarrow CHN -
USA + \nrightarrow CHN +	1.708	11.788	7.739	6.217	USA + \nrightarrow CHN +
USA - \nrightarrow CHN -	5.638	11.333	7.648	6.002	USA - \nrightarrow CHN -
MEX + \nrightarrow CHN +	2.919	9.547	6.449	4.720	MEX + \nrightarrow CHN +
MEX - \nrightarrow CHN -	2.471	10.169	5.880	4.397	MEX - \nrightarrow CHN -
BRA + \nrightarrow CHN +	2.167	9.338	6.039	4.340	BRA + \nrightarrow CHN +
BRA - \nrightarrow CHN -	1.313	10.336	5.937	4.689	BRA - \nrightarrow CHN -
South Korea as a recipient					
ESP + \nrightarrow KOR +	9.247***	8.283	5.594	4.439	ESP + \Rightarrow KOR +
ESP - \nrightarrow KOR -	13.016***	10.404	6.661	4.953	ESP - \Rightarrow KOR -
RUS + \nrightarrow KOR +	1.536	10.191	6.098	4.614	RUS + \nrightarrow KOR +
RUS - \nrightarrow KOR -	0.476	8.302	6.001	4.562	RUS - \nrightarrow KOR -
HUN + \nrightarrow KOR +	2.827	9.315	5.887	4.630	HUN + \nrightarrow KOR +
HUN - \nrightarrow KOR -	10.078***	8.542	5.933	4.746	HUN - \Rightarrow KOR -
TUR + \nrightarrow KOR +	0.232	9.215	6.083	4.715	TUR + \nrightarrow KOR +
TUR - \nrightarrow KOR -	1.889	9.169	5.730	4.434	TUR - \nrightarrow KOR -
ZAF + \nrightarrow KOR +	6.569**	9.655	5.997	4.648	ZAF + \Rightarrow KOR +
ZAF - \nrightarrow KOR -	22.430***	8.780	5.768	4.576	ZAF - \Rightarrow KOR -
CAN + \nrightarrow KOR +	5.671*	10.363	6.463	4.779	CAN + \Rightarrow KOR +
CAN - \nrightarrow KOR -	2.165	10.146	5.964	4.512	CAN - \nrightarrow KOR -
USA + \nrightarrow KOR +	6.717*	12.249	7.747	6.096	USA + \Rightarrow KOR +
USA - \nrightarrow KOR -	5.837	12.488	9.769	8.073	USA - \nrightarrow KOR -
MEX + \nrightarrow KOR +	1.047	9.968	6.339	4.911	MEX + \nrightarrow KOR +
MEX - \nrightarrow KOR -	5.983*	8.959	5.749	4.390	MEX - \Rightarrow KOR -
BRA + \nrightarrow KOR +	2.604	10.851	6.550	5.057	BRA + \nrightarrow KOR +
BRA - \nrightarrow KOR -	3.431	10.663	5.777	4.633	BRA - \nrightarrow KOR -

Table 2 (continued)

Malaysia as a recipient					
TUR + \nRightarrow MYS +	3.756	9.057	6.086	4.603	TUR + \nRightarrow MYS +
TUR - \nRightarrow MYS -	7.664**	8.694	5.853	4.333	TUR - \Rightarrow MYS -
CAN + \nRightarrow MYS +	12.888***	9.359	6.311	4.557	CAN + \Rightarrow MYS +
CAN - \nRightarrow MYS -	24.027***	10.979	7.414	6.015	CAN - \Rightarrow MYS -
USA + \nRightarrow MYS +	7.518*	12.007	8.392	6.388	USA + \Rightarrow MYS +
USA - \nRightarrow MYS -	17.649***	11.854	7.815	6.244	USA - \Rightarrow MYS -
MEX + \nRightarrow MYS +	5.067	12.845	8.544	6.420	MEX + \nRightarrow MYS +
MEX - \nRightarrow MYS -	11.040***	10.896	7.340	5.724	MEX - \Rightarrow MYS -
BRA + \nRightarrow MYS +	1.845	9.148	5.914	4.810	BRA + \nRightarrow MYS +
BRA - \nRightarrow MYS -	3.906	7.728	5.409	4.230	BRA - \nRightarrow MYS -
Taiwan as a recipient					
GER + \nRightarrow TWN +	23.883***	12.809	8.061	6.344	GER + \Rightarrow TWN +
GER - \nRightarrow TWN -	42.466***	15.140	10.077	8.215	GER - \Rightarrow TWN -
FRA + \nRightarrow TWN +	15.639***	11.709	7.500	6.438	FRA + \Rightarrow TWN +
FRA - \nRightarrow TWN -	25.158***	15.381	10.208	8.194	FRA - \nRightarrow TWN -
ESP + \nRightarrow TWN +	13.784***	10.150	6.318	5.013	ESP + \Rightarrow TWN +
ESP - \nRightarrow TWN -	8.089**	8.776	5.826	4.470	ESP - \Rightarrow TWN -
SUI + \nRightarrow TWN +	25.578***	11.792	8.003	6.472	SUI + \Rightarrow TWN +
SUI - \nRightarrow TWN -	28.845***	15.129	10.200	8.140	SUI - \Rightarrow TWN -
RUS + \nRightarrow TWN +	6.130*	10.385	6.316	4.651	RUS + \Rightarrow TWN +
RUS - \nRightarrow TWN -	5.091*	10.567	6.346	4.817	RUS - \Rightarrow TWN -
HUN + \nRightarrow TWN +	7.672**	9.765	6.128	4.736	HUN + \Rightarrow TWN +
HUN - \nRightarrow TWN -	4.141	10.156	6.270	4.642	HUN - \nRightarrow TWN -
TUR + \nRightarrow TWN +	5.653*	10.169	5.953	4.523	TUR + \Rightarrow TWN +
TUR - \nRightarrow TWN -	8.918**	9.230	5.764	4.564	TUR - \Rightarrow TWN -
ZAF + \nRightarrow TWN +	10.536**	11.776	7.711	6.183	ZAF + \Rightarrow TWN +
ZAF - \nRightarrow TWN -	10.839***	9.921	6.174	4.670	ZAF - \Rightarrow TWN -
CAN + \nRightarrow TWN +	8.949**	10.270	5.672	4.258	CAN + \Rightarrow TWN +
CAN - \nRightarrow TWN -	17.895***	8.330	5.578	4.374	CAN - \Rightarrow TWN -
USA + \nRightarrow TWN +	9.069**	11.584	8.486	6.618	USA + \Rightarrow TWN +
USA - \nRightarrow TWN -	30.448***	13.141	9.682	8.090	USA - \Rightarrow TWN -
MEX + \nRightarrow TWN +	1.959	10.180	5.723	4.323	MEX + \nRightarrow TWN +
MEX - \nRightarrow TWN -	23.797***	12.354	7.957	6.251	MEX - \Rightarrow TWN -
BRA + \nRightarrow TWN +	0.467	9.514	6.276	4.817	BRA + \nRightarrow TWN +
BRA - \nRightarrow TWN -	5.298*	10.008	6.105	4.641	BRA - \Rightarrow TWN -
India as a recipient					
CAN + \nRightarrow IND +	0.563	9.831	6.310	4.792	CAN + \nRightarrow IND +
CAN - \nRightarrow IND -	3.065	8.857	6.059	4.369	CAN - \nRightarrow IND -
BRA + \nRightarrow IND +	4.117	9.461	6.052	4.870	BRA + \nRightarrow IND +
BRA - \nRightarrow IND -	1.430	10.465	5.943	4.715	BRA - \nRightarrow IND -

Notes: The critical values for the asymmetric causality test are calculated using a bootstrap algorithm with leverage correction. The highlighted results indicate: *the rejection of the Null Hypothesis of no causality at the 10% significance level; **the rejection of the Null Hypothesis of no causality at the 5% significance level; ***the rejection of the Null Hypothesis of no causality at the 5% significance level.

Table 3. The asymmetric Causality Test Results for Volatility, Asia.

Null Hypothesis	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Conclusion
Hong Kong as a recipient					
TUR \nrightarrow HKG +	1.133	9.258	5.614	4.444	TUR \nrightarrow HKG +
TUR \nrightarrow HKG -	0.525	9.389	6.138	4.967	TUR \nrightarrow HKG -
CAN \nrightarrow HKG +	3.447	10.571	5.816	4.498	CAN \nrightarrow HKG +
CAN \nrightarrow HKG -	2.766	9.751	6.317	4.839	CAN \nrightarrow HKG -
USA \nrightarrow HKG +	4.112	11.588	7.853	6.290	USA \nrightarrow HKG +
USA \nrightarrow HKG -	1.507	11.842	8.336	6.642	USA \nrightarrow HKG -
MEX \nrightarrow HKG +	0.944	10.475	6.306	4.672	MEX \nrightarrow HKG +
MEX \nrightarrow HKG -	5.138*	10.390	6.787	4.825	MEX \nrightarrow HKG -
BRA \nrightarrow HKG +	4.748*	9.252	5.860	4.551	BRA \Rightarrow HKG +
BRA \nrightarrow HKG -	2.365	10.598	6.251	4.699	BRA \nrightarrow HKG -
Japan as a recipient					
ESP \nrightarrow JPN +	0.658	9.217	6.152	4.633	ESP \nrightarrow JPN +
ESP \nrightarrow JPN -	1.912	8.769	5.712	4.198	ESP \nrightarrow JPN -
RUS \nrightarrow JPN +	0.986	9.835	5.954	4.503	RUS \nrightarrow JPN +
RUS \nrightarrow JPN -	0.714	9.239	5.683	4.439	RUS \nrightarrow JPN -
HUN \nrightarrow JPN +	0.365	8.959	5.933	4.548	HUN \nrightarrow JPN +
HUN \nrightarrow JPN -	1.246	9.432	6.162	4.615	HUN \nrightarrow JPN -
TUR \nrightarrow JPN +	3.995	10.425	6.144	4.714	TUR \nrightarrow JPN +
TUR \nrightarrow JPN -	2.864	9.897	5.975	4.616	TUR \nrightarrow JPN -
ZAF \nrightarrow JPN +	18.407***	14.503	9.791	8.070	ZAF \Rightarrow JPN +
ZAF \nrightarrow JPN -	9.955**	11.278	8.013	6.582	ZAF \Rightarrow JPN -
CAN \nrightarrow JPN +	9.108**	9.851	6.234	4.708	CAN \Rightarrow JPN +
CAN \nrightarrow JPN -	0.600	10.021	6.075	4.708	CAN \nrightarrow JPN -
USA \nrightarrow JPN +	1.451	13.534	9.573	8.050	USA \nrightarrow JPN +
USA \nrightarrow JPN -	5.358	13.711	8.239	6.470	USA \nrightarrow JPN -
MEX \nrightarrow JPN +	10.161**	11.211	7.391	5.976	MEX \Rightarrow JPN +
MEX \nrightarrow JPN -	0.908	9.469	5.943	4.432	MEX \nrightarrow JPN -
BRA \nrightarrow JPN +	3.717	9.093	5.946	4.545	BRA \nrightarrow JPN +
BRA \nrightarrow JPN -	6.836*	10.861	7.790	6.286	BRA \Rightarrow JPN -
Singapore as a recipient					
TUR \nrightarrow SGP +	2.008	10.181	6.065	4.753	TUR \nrightarrow SGP +
TUR \nrightarrow SGP -	0.886	9.836	6.340	4.776	TUR \nrightarrow SGP -
CAN \nrightarrow SGP +	1.276	12.827	6.391	4.819	CAN \nrightarrow SGP +
CAN \nrightarrow SGP -	0.077	13.317	6.419	4.650	CAN \nrightarrow SGP -
USA \nrightarrow SGP +	5.485	11.511	8.056	6.466	USA \nrightarrow SGP +
USA \nrightarrow SGP -	5.752	13.395	7.969	6.270	USA \nrightarrow SGP -
MEX \nrightarrow SGP +	5.088*	10.875	6.058	4.623	MEX \Rightarrow SGP +
MEX \nrightarrow SGP -	2.254	9.713	5.655	4.215	MEX \nrightarrow SGP -
BRA \nrightarrow SGP +	4.224	9.879	6.188	4.726	BRA \nrightarrow SGP +
BRA \nrightarrow SGP -	4.645	11.854	6.462	4.659	BRA \nrightarrow SGP -
China as a recipient					
TUR \nrightarrow CHN +	3.939	10.008	6.135	4.521	TUR \nrightarrow CHN +
TUR \nrightarrow CHN -	4.462	10.168	6.136	4.574	TUR \nrightarrow CHN -
CAN \nrightarrow CHN +	1.535	9.236	6.123	4.802	CAN \nrightarrow CHN +
CAN \nrightarrow CHN -	0.260	9.617	6.079	4.725	CAN \nrightarrow CHN -
USA \nrightarrow CHN +	5.442	10.994	7.384	5.768	USA \nrightarrow CHN +
USA \nrightarrow CHN -	1.814	12.512	7.334	6.234	USA \nrightarrow CHN -
MEX \nrightarrow CHN +	0.626	9.795	5.951	4.509	MEX \nrightarrow CHN +
MEX \nrightarrow CHN -	4.423*	8.860	5.943	4.256	MEX \Rightarrow CHN -
BRA \nrightarrow CHN +	0.570	9.821	6.332	4.869	BRA \nrightarrow CHN +
BRA \nrightarrow CHN -	1.534	10.488	6.259	5.007	BRA \nrightarrow CHN -
South Korea as a recipient					
ESP \nrightarrow KOR +	13.550***	11.110	6.708	4.917	ESP \Rightarrow KOR +
ESP \nrightarrow KOR -	1.910	10.222	6.629	4.595	ESP \nrightarrow KOR -
RUS \nrightarrow KOR +	11.251***	9.330	5.508	4.287	RUS \Rightarrow KOR +
RUS \nrightarrow KOR -	3.043	12.017	8.448	6.461	RUS \nrightarrow KOR -
HUN \nrightarrow KOR +	8.855**	10.739	6.084	4.664	HUN \Rightarrow KOR +
HUN \nrightarrow KOR -	2.516	9.050	5.872	4.597	HUN \nrightarrow KOR -
TUR \nrightarrow KOR +	4.635	9.113	5.778	4.713	TUR \nrightarrow KOR +
TUR \nrightarrow KOR -	1.102	9.074	5.966	4.709	TUR \nrightarrow KOR -
ZAF \nrightarrow KOR +	27.548***	9.145	5.626	4.535	ZAF \Rightarrow KOR +
ZAF \nrightarrow KOR -	11.892**	12.449	8.596	6.411	ZAF \Rightarrow KOR -
CAN \nrightarrow KOR +	1.129	10.385	6.635	4.894	CAN \nrightarrow KOR +
CAN \nrightarrow KOR -	4.769*	10.202	5.978	4.597	CAN \Rightarrow KOR -
USA \nrightarrow KOR +	3.780	13.066	9.222	7.522	USA \nrightarrow KOR +
USA \nrightarrow KOR -	5.853	12.093	8.546	6.304	USA \nrightarrow KOR -
MEX \nrightarrow KOR +	7.654**	9.357	6.165	4.643	MEX \Rightarrow KOR +
MEX \nrightarrow KOR -	0.648	10.154	6.755	4.846	MEX \nrightarrow KOR -
BRA \nrightarrow KOR +	2.272	11.271	5.941	4.580	BRA \nrightarrow KOR +
BRA \nrightarrow KOR -	4.061	10.114	6.213	4.742	BRA \nrightarrow KOR -

Table 3 (continued)

Malaysia as a recipient					
TUR + \nRightarrow MYS +	2.245	8.671	5.900	4.464	TUR + \nRightarrow MYS +
TUR - \nRightarrow MYS -	1.509	9.421	5.706	4.650	TUR - \nRightarrow MYS -
CAN + \nRightarrow MYS +	6.322**	9.896	5.992	4.545	CAN + \Rightarrow MYS +
CAN - \nRightarrow MYS -	8.966**	9.122	5.881	4.684	CAN - \Rightarrow MYS -
USA + \nRightarrow MYS +	9.480**	11.363	7.811	6.340	USA + \Rightarrow MYS +
USA - \nRightarrow MYS -	1.532	12.854	8.705	6.616	USA - \nRightarrow MYS -
MEX + \nRightarrow MYS +	0.407	9.563	6.099	4.443	MEX + \nRightarrow MYS +
MEX - \nRightarrow MYS -	1.081	9.483	5.528	4.575	MEX - \nRightarrow MYS -
BRA + \nRightarrow MYS +	0.018	9.640	6.177	4.533	BRA + \nRightarrow MYS +
BRA - \nRightarrow MYS -	2.990	8.976	5.966	4.545	BRA - \nRightarrow MYS -
Taiwan as a recipient					
GER + \nRightarrow TWN +	34.854***	15.030	9.623	7.573	GER + \Rightarrow TWN +
GER - \nRightarrow TWN -	23.357***	12.577	7.716	6.365	GER - \Rightarrow TWN -
FRA + \nRightarrow TWN +	9.821**	13.373	7.655	6.308	FRA + \Rightarrow TWN +
FRA - \nRightarrow TWN -	17.806***	12.047	8.158	6.563	FRA - \Rightarrow TWN -
ESP + \nRightarrow TWN +	7.048**	8.819	5.606	4.421	ESP + \Rightarrow TWN +
ESP - \nRightarrow TWN -	12.079**	13.907	7.663	6.043	ESP - \Rightarrow TWN -
SUI + \nRightarrow TWN +	31.766***	14.458	10.028	8.121	SUI + \Rightarrow TWN +
SUI - \nRightarrow TWN -	28.232***	13.448	9.607	8.176	SUI - \Rightarrow TWN -
RUS + \nRightarrow TWN +	8.644**	8.991	5.863	4.784	RUS + \Rightarrow TWN +
RUS - \nRightarrow TWN -	5.642*	10.145	5.883	4.444	RUS - \Rightarrow TWN -
HUN + \nRightarrow TWN +	7.143**	9.690	6.318	4.875	HUN + \Rightarrow TWN +
HUN - \nRightarrow TWN -	5.383*	9.553	5.695	4.590	HUN - \Rightarrow TWN -
TUR + \nRightarrow TWN +	0.626	8.834	5.854	4.601	TUR + \nRightarrow TWN +
TUR - \nRightarrow TWN -	2.562	10.483	5.530	4.383	TUR - \nRightarrow TWN -
ZAF + \nRightarrow TWN +	22.471***	12.523	8.623	6.998	ZAF + \Rightarrow TWN +
ZAF - \nRightarrow TWN -	12.140***	11.227	8.081	6.221	ZAF - \Rightarrow TWN -
CAN + \nRightarrow TWN +	2.841	9.965	5.763	4.327	CAN + \nRightarrow TWN +
CAN - \nRightarrow TWN -	2.628	9.470	5.726	4.353	CAN - \nRightarrow TWN -
USA + \nRightarrow TWN +	22.191***	13.414	9.698	8.323	USA + \Rightarrow TWN +
USA - \nRightarrow TWN -	9.436**	11.820	8.142	6.460	USA - \Rightarrow TWN -
MEX + \nRightarrow TWN +	20.325***	12.591	8.168	6.239	MEX + \Rightarrow TWN +
MEX - \nRightarrow TWN -	2.287	8.784	5.670	4.520	MEX - \nRightarrow TWN -
BRA + \nRightarrow TWN +	6.905**	8.626	5.681	4.566	BRA + \Rightarrow TWN +
BRA - \nRightarrow TWN -	0.740	10.364	5.835	4.485	BRA - \nRightarrow TWN -
India as a recipient					
CAN + \nRightarrow IND +	1.817	8.233	5.650	4.378	CAN + \nRightarrow IND +
CAN - \nRightarrow IND -	0.179	9.653	6.222	4.816	CAN - \nRightarrow IND -
BRA + \nRightarrow IND +	0.346	9.228	5.654	4.467	BRA + \nRightarrow IND +
BRA - \nRightarrow IND -	3.522	9.704	6.450	4.529	BRA - \nRightarrow IND -

Notes: The critical values for the asymmetric causality test are calculated using a bootstrap algorithm with leverage correction. The highlighted results indicate: *the rejection of the Null Hypothesis of no causality at the 10% significance level; **the rejection of the Null Hypothesis of no causality at the 5% significance level; ***the rejection of the Null Hypothesis of no causality at the 5% significance level.

Table 4. The asymmetric Causality Test Results for Returns, Europe and Africa.

Null Hypothesis	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Conclusion
Germany as a recipient					
TWN + \nrightarrow GER +	24.892***	11.701	7.390	6.082	TWN + \Rightarrow GER +
TWN - \nrightarrow GER -	31.616***	12.655	9.619	7.851	TWN - \Rightarrow GER -
France as a recipient					
TWN + \nrightarrow FRA +	11.106***	10.811	7.561	5.999	TWN + \Rightarrow FRA +
TWN - \nrightarrow FRA -	18.448***	12.556	9.369	7.755	TWN - \Rightarrow FRA -
Spain as a recipient					
JPN + \nrightarrow ESP +	84.248***	10.243	5.963	4.246	JPN + \Rightarrow ESP +
JPN - \nrightarrow ESP -	56.475***	8.791	5.816	4.393	JPN - \Rightarrow ESP -
KOR + \nrightarrow ESP +	74.718***	9.074	5.820	4.475	KOR + \Rightarrow ESP +
KOR - \nrightarrow ESP -	84.482***	8.574	5.875	4.436	KOR - \Rightarrow ESP -
TWN + \nrightarrow ESP +	6.479**	9.050	6.093	4.714	TWN + \Rightarrow ESP +
TWN - \nrightarrow ESP -	1.311	9.962	6.386	4.675	TWN - \nrightarrow ESP -
Switzerland as a recipient					
TWN + \nrightarrow SUI +	19.068***	12.746	8.046	6.257	TWN + \Rightarrow SUI +
TWN - \nrightarrow SUI -	38.717***	15.054	9.736	8.165	TWN - \Rightarrow SUI -
Russia as a recipient					
JPN + \nrightarrow RUS +	12.458***	8.813	5.963	4.538	JPN + \Rightarrow RUS +
JPN - \nrightarrow RUS -	5.390*	9.066	5.552	4.370	JPN - \nrightarrow RUS -
KOR + \nrightarrow RUS +	24.169***	10.385	6.480	4.749	KOR + \Rightarrow RUS +
KOR - \nrightarrow RUS -	8.471**	9.156	6.399	4.967	KOR - \Rightarrow RUS -
TWN + \nrightarrow RUS +	2.977	8.230	5.970	4.547	TWN + \nrightarrow RUS +
TWN - \nrightarrow RUS -	4.687	8.737	6.220	4.719	TWN - \nrightarrow RUS -
Hungary as a recipient					
JPN + \nrightarrow HUN +	25.613***	9.075	6.599	4.748	JPN + \Rightarrow HUN +
JPN - \nrightarrow HUN -	11.951***	9.822	6.040	4.384	JPN - \Rightarrow HUN -
KOR + \nrightarrow HUN +	28.610***	8.358	5.855	4.604	KOR + \Rightarrow HUN +
KOR - \nrightarrow HUN -	21.609***	10.547	6.562	4.899	KOR - \Rightarrow HUN -
TWN + \nrightarrow HUN +	1.126	10.764	6.048	4.665	TWN + \nrightarrow HUN +
TWN - \nrightarrow HUN -	3.171	9.386	6.225	4.841	TWN - \nrightarrow HUN -
Turkey as a recipient					
HKG + \nrightarrow TUR +	0.815	11.574	6.582	4.952	HKG + \nrightarrow TUR +
HKG - \nrightarrow TUR -	4.869*	8.647	5.753	4.498	HKG - \Rightarrow TUR -
JPN + \nrightarrow TUR +	37.940***	10.140	6.358	4.996	JPN + \Rightarrow TUR +
JPN - \nrightarrow TUR -	18.454***	8.988	5.998	4.623	JPN - \Rightarrow TUR -
SGP + \nrightarrow TUR +	43.955***	9.657	6.117	4.617	SGP + \Rightarrow TUR +
SGP - \nrightarrow TUR -	23.844***	9.807	6.442	5.022	SGP - \Rightarrow TUR -
CHN + \nrightarrow TUR +	3.959	10.729	6.148	4.449	CHN + \nrightarrow TUR +
CHN - \nrightarrow TUR -	3.668	9.076	6.165	4.852	CHN - \nrightarrow TUR -
KOR + \nrightarrow TUR +	41.910***	9.352	6.345	4.832	KOR + \Rightarrow TUR +
KOR - \nrightarrow TUR -	14.251***	9.897	5.749	4.550	KOR - \Rightarrow TUR -
MYS + \nrightarrow TUR +	0.052	10.229	5.904	4.735	MYS + \nrightarrow TUR +
MYS - \nrightarrow TUR -	3.837	8.766	5.673	4.482	MYS - \nrightarrow TUR -
TWN + \nrightarrow TUR +	2.810	9.015	5.982	4.643	TWN + \nrightarrow TUR +
TWN - \nrightarrow TUR -	4.372	9.633	6.422	4.944	TWN - \nrightarrow TUR -
South Africa as a recipient					
JPN + \nrightarrow ZAF +	53.523***	11.790	6.798	5.044	JPN + \Rightarrow ZAF +
JPN - \nrightarrow ZAF -	38.956***	9.328	5.917	4.501	JPN - \Rightarrow ZAF -
KOR + \nrightarrow ZAF +	52.113***	10.496	6.481	5.207	KOR + \Rightarrow ZAF +
KOR - \nrightarrow ZAF -	42.238***	8.717	5.529	4.521	KOR - \Rightarrow ZAF -
TWN + \nrightarrow ZAF +	23.725***	12.639	8.122	6.265	TWN + \Rightarrow ZAF +
TWN - \nrightarrow ZAF -	12.092***	8.983	6.204	4.737	TWN - \Rightarrow ZAF -

Notes: The critical values for the asymmetric causality test are calculated using a bootstrap algorithm with leverage correction. The highlighted results indicate: *the rejection of the Null Hypothesis of no causality at the 10% significance level; **the rejection of the Null Hypothesis of no causality at the 5% significance level; ***the rejection of the Null Hypothesis of no causality at the 5% significance level.

Table 5. The asymmetric Causality Test Results for Volatility, Europe and Africa.

Null Hypothesis	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Conclusion
Panel A. Asian Region					
Germany as a recipient					
TWN + \nrightarrow GER +	41.319***	13.910	9.870	7.738	TWN + \Rightarrow GER +
TWN - \nrightarrow GER -	15.030***	11.652	7.413	5.788	TWN - \Rightarrow GER -
France as a recipient					
TWN + \nrightarrow FRA +	20.007***	12.665	8.298	6.394	TWN + \Rightarrow FRA +
TWN - \nrightarrow FRA -	13.788***	11.670	7.592	6.100	TWN - \Rightarrow FRA -
Spain as a recipient					
JPN + \nrightarrow ESP +	18.007***	9.688	6.597	4.739	JPN + \Rightarrow ESP +
JPN - \nrightarrow ESP -	26.846***	10.909	6.268	4.720	JPN - \Rightarrow ESP -
KOR + \nrightarrow ESP +	33.074***	9.318	6.290	5.030	KOR + \Rightarrow ESP +
KOR - \nrightarrow ESP -	31.155***	9.158	5.867	4.632	KOR - \Rightarrow ESP -
TWN + \nrightarrow ESP +	6.448**	9.410	5.885	4.378	TWN + \Rightarrow ESP +
TWN - \nrightarrow ESP -	10.454**	11.953	7.882	6.336	TWN - \Rightarrow ESP -
Switzerland as a recipient					
TWN + \nrightarrow SUI +	45.318***	14.585	9.925	7.877	TWN + \Rightarrow SUI +
TWN - \nrightarrow SUI -	25.762***	14.134	9.583	7.690	TWN - \Rightarrow SUI -
Russia as a recipient					
JPN + \nrightarrow RUS +	3.363	9.427	6.094	4.601	JPN + \nrightarrow RUS +
JPN - \nrightarrow RUS -	7.588**	10.006	5.871	4.588	JPN - \Rightarrow RUS -
KOR + \nrightarrow RUS +	8.935***	10.132	6.397	4.774	KOR + \Rightarrow RUS +
KOR - \nrightarrow RUS -	37.453***	10.872	8.003	6.364	KOR - \Rightarrow RUS -
TWN + \nrightarrow RUS +	9.141**	9.508	6.209	4.781	TWN + \Rightarrow RUS +
TWN - \nrightarrow RUS -	6.515**	9.660	6.388	4.982	TWN - \Rightarrow RUS -
Hungary as a recipient					
JPN + \nrightarrow HUN +	13.688***	10.943	5.924	4.626	JPN + \Rightarrow HUN +
JPN - \nrightarrow HUN -	18.890***	8.938	5.945	4.999	JPN - \Rightarrow HUN -
KOR + \nrightarrow HUN +	24.749***	9.888	6.356	4.801	KOR + \Rightarrow HUN +
KOR - \nrightarrow HUN -	35.489***	9.814	6.381	4.607	KOR - \Rightarrow HUN -
TWN + \nrightarrow HUN +	10.178***	8.982	5.825	4.403	TWN + \Rightarrow HUN +
TWN - \nrightarrow HUN -	5.845**	10.233	5.736	4.551	TWN - \Rightarrow HUN -
Turkey as a recipient					
HKG + \nrightarrow TUR +	4.291	9.203	6.129	4.945	HKG + \nrightarrow TUR +
HKG - \nrightarrow TUR -	1.266	10.771	6.553	4.644	HKG - \nrightarrow TUR -
JPN + \nrightarrow TUR +	13.552***	11.109	6.202	4.664	JPN + \Rightarrow TUR +
JPN - \nrightarrow TUR -	20.389***	9.520	6.577	5.005	JPN - \Rightarrow TUR -
SGP + \nrightarrow TUR +	2.136	9.939	6.022	4.573	SGP + \nrightarrow TUR +
SGP - \nrightarrow TUR -	11.679***	9.717	5.780	4.403	SGP - \Rightarrow TUR -
CHN + \nrightarrow TUR +	2.889	9.625	6.475	4.720	CHN + \nrightarrow TUR +
CHN - \nrightarrow TUR -	2.852	9.793	6.133	4.605	CHN - \nrightarrow TUR -
KOR + \nrightarrow TUR +	7.159**	9.806	6.320	4.672	KOR + \Rightarrow TUR +
KOR - \nrightarrow TUR -	26.605***	10.216	6.076	4.506	KOR - \Rightarrow TUR -
MYS + \nrightarrow TUR +	0.858	8.874	5.849	4.472	MYS + \nrightarrow TUR +
MYS - \nrightarrow TUR -	2.522	9.915	6.305	4.802	MYS - \nrightarrow TUR -
TWN + \nrightarrow TUR +	7.754**	8.668	5.547	4.315	TWN + \Rightarrow TUR +
TWN - \nrightarrow TUR -	2.395	9.585	5.970	4.559	TWN - \nrightarrow TUR -
South Africa as a recipient					
JPN + \nrightarrow ZAF +	40.322***	12.791	9.632	7.827	JPN + \Rightarrow ZAF +
JPN - \nrightarrow ZAF -	45.923***	11.785	8.175	6.435	JPN - \Rightarrow ZAF -
KOR + \nrightarrow ZAF +	23.070***	8.666	6.469	4.893	KOR + \Rightarrow ZAF +
KOR - \nrightarrow ZAF -	46.793***	12.443	7.938	6.053	KOR - \Rightarrow ZAF -
TWN + \nrightarrow ZAF +	27.100***	12.640	8.006	6.418	TWN + \Rightarrow ZAF +
TWN - \nrightarrow ZAF -	20.008***	13.346	8.118	6.440	TWN - \Rightarrow ZAF -

Notes: The critical values for the asymmetric causality test are calculated using a bootstrap algorithm with leverage correction. The highlighted results indicate: *the rejection of the Null Hypothesis of no causality at the 10% significance level; **the rejection of the Null Hypothesis of no causality at the 5% significance level; ***the rejection of the Null Hypothesis of no causality at the 5% significance level.

Table 6. The asymmetric Causality Test Results for Returns, the Americas.

Null Hypothesis	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Conclusion
Canada as a recipient					
HKG + \nRightarrow CAN +	<u>12.428***</u>	8.773	5.937	4.457	<u>HKG + \Rightarrow CAN +</u>
HKG - \nRightarrow CAN -	1.991	10.322	6.679	4.924	HKG - \nRightarrow CAN -
JPN + \nRightarrow CAN +	<u>66.091***</u>	10.133	6.345	4.809	<u>JPN + \Rightarrow CAN +</u>
JPN - \nRightarrow CAN -	<u>31.800***</u>	9.205	6.256	4.677	<u>JPN - \Rightarrow CAN -</u>
SGP + \nRightarrow CAN +	<u>137.978***</u>	10.366	6.398	4.729	<u>SGP + \Rightarrow CAN +</u>
SGP - \nRightarrow CAN -	<u>89.158***</u>	9.761	6.201	4.626	<u>SGP - \Rightarrow CAN -</u>
CHN + \nRightarrow CAN +	0.820	9.560	6.166	4.704	CHN + \nRightarrow CAN +
CHN - \nRightarrow CAN -	2.738	9.216	6.195	4.655	CHN - \nRightarrow CAN -
KOR + \nRightarrow CAN +	<u>103.583***</u>	9.608	6.051	4.593	<u>KOR + \Rightarrow CAN +</u>
KOR - \nRightarrow CAN -	<u>89.253***</u>	9.011	5.604	4.535	<u>KOR - \Rightarrow CAN -</u>
MYS + \nRightarrow CAN +	3.430	9.809	6.059	4.571	MYS + \nRightarrow CAN +
MYS - \nRightarrow CAN -	<u>21.125***</u>	11.610	8.651	6.631	<u>MYS - \Rightarrow CAN -</u>
TWN + \nRightarrow CAN +	0.166	9.238	5.999	4.707	TWN + \nRightarrow CAN +
TWN - \nRightarrow CAN -	<u>8.068**</u>	9.579	6.103	4.748	<u>TWN - \Rightarrow CAN -</u>
IND + \nRightarrow CAN +	<u>14.799***</u>	9.439	6.009	4.533	<u>IND + \Rightarrow CAN +</u>
IND - \nRightarrow CAN -	<u>6.887**</u>	10.200	6.258	4.610	<u>IND - \Rightarrow CAN -</u>
USA as a recipient					
HKG + \nRightarrow USA +	<u>22.522***</u>	11.165	7.989	6.617	<u>HKG + \Rightarrow USA +</u>
HKG - \nRightarrow USA -	5.225	12.180	8.273	6.618	HKG - \nRightarrow USA -
JPN + \nRightarrow USA +	<u>104.125***</u>	12.840	8.279	6.418	<u>JPN + \Rightarrow USA +</u>
JPN - \nRightarrow USA -	<u>110.052***</u>	13.315	9.952	7.863	<u>JPN - \Rightarrow USA -</u>
SGP + \nRightarrow USA +	<u>178.320***</u>	10.757	7.639	6.477	<u>SGP + \Rightarrow USA +</u>
SGP - \nRightarrow USA -	<u>137.842***</u>	12.002	8.273	6.438	<u>SGP - \Rightarrow USA -</u>
CHN + \nRightarrow USA +	3.980	12.396	7.924	6.093	CHN + \nRightarrow USA +
CHN - \nRightarrow USA -	4.600	12.658	8.133	6.554	CHN - \nRightarrow USA -
KOR + \nRightarrow USA +	<u>120.354***</u>	12.381	7.744	6.096	<u>KOR + \Rightarrow USA +</u>
KOR - \nRightarrow USA -	<u>121.720***</u>	14.597	9.768	7.888	<u>KOR - \Rightarrow USA -</u>
MYS + \nRightarrow USA +	<u>6.805*</u>	12.328	8.099	6.633	<u>MYS + \Rightarrow USA +</u>
MYS - \nRightarrow USA -	<u>22.874***</u>	11.300	8.004	6.463	<u>MYS - \Rightarrow USA -</u>
TWN + \nRightarrow USA +	<u>17.115***</u>	12.504	7.484	6.079	<u>TWN + \Rightarrow USA +</u>
TWN - \nRightarrow USA -	<u>47.911***</u>	14.710	10.086	8.005	<u>TWN - \Rightarrow USA -</u>
Mexico as a recipient					
HKG + \nRightarrow MEX +	<u>28.187***</u>	9.148	6.252	4.873	<u>HKG + \Rightarrow MEX +</u>
HKG - \nRightarrow MEX -	<u>8.538**</u>	9.376	6.814	5.035	<u>HKG - \Rightarrow MEX -</u>
JPN + \nRightarrow MEX +	<u>34.769***</u>	9.638	6.259	4.830	<u>JPN + \Rightarrow MEX +</u>
JPN - \nRightarrow MEX -	<u>19.203***</u>	8.561	5.735	4.390	<u>JPN - \Rightarrow MEX -</u>
SGP + \nRightarrow MEX +	<u>110.157***</u>	9.103	6.346	4.864	<u>SGP + \Rightarrow MEX +</u>
SGP - \nRightarrow MEX -	<u>73.439***</u>	11.251	7.929	6.174	<u>SGP - \Rightarrow MEX -</u>
CHN + \nRightarrow MEX +	<u>8.134**</u>	9.159	6.167	4.519	<u>CHN + \Rightarrow MEX +</u>
CHN - \nRightarrow MEX -	<u>5.454*</u>	9.561	5.965	4.637	<u>CHN - \Rightarrow MEX -</u>
KOR + \nRightarrow MEX +	<u>54.564***</u>	8.859	6.161	4.692	<u>KOR + \Rightarrow MEX +</u>
KOR - \nRightarrow MEX -	<u>26.865***</u>	10.521	6.061	4.670	<u>KOR - \Rightarrow MEX -</u>
MYS + \nRightarrow MEX +	<u>12.832***</u>	10.844	7.994	6.263	<u>MYS + \Rightarrow MEX +</u>
MYS - \nRightarrow MEX -	<u>17.524***</u>	11.903	8.031	6.522	<u>MYS - \Rightarrow MEX -</u>
TWN + \nRightarrow MEX +	<u>5.526*</u>	10.248	6.133	4.670	<u>TWN + \Rightarrow MEX +</u>
TWN - \nRightarrow MEX -	<u>11.497***</u>	10.707	7.861	6.074	<u>TWN - \Rightarrow MEX -</u>
Brazil as a recipient					
HKG + \nRightarrow BRA +	<u>21.549***</u>	9.039	5.644	4.602	<u>HKG + \Rightarrow BRA +</u>
HKG - \nRightarrow BRA -	<u>8.835**</u>	10.009	6.473	4.560	<u>HKG - \Rightarrow BRA -</u>
JPN + \nRightarrow BRA +	<u>37.637***</u>	9.236	6.139	4.819	<u>JPN + \Rightarrow BRA +</u>
JPN - \nRightarrow BRA -	<u>23.751***</u>	10.231	6.578	4.739	<u>JPN - \Rightarrow BRA -</u>
SGP + \nRightarrow BRA +	<u>101.751***</u>	10.385	5.847	4.500	<u>SGP + \Rightarrow BRA +</u>
SGP - \nRightarrow BRA -	<u>92.114***</u>	10.361	7.367	6.000	<u>SGP - \Rightarrow BRA -</u>
CHN + \nRightarrow BRA +	4.473	9.543	5.974	4.516	CHN + \nRightarrow BRA +
CHN - \nRightarrow BRA -	1.853	9.895	6.399	4.983	CHN - \nRightarrow BRA -
KOR + \nRightarrow BRA +	<u>57.088***</u>	9.191	5.852	4.731	<u>KOR + \Rightarrow BRA +</u>
KOR - \nRightarrow BRA -	<u>35.212***</u>	8.962	6.625	5.115	<u>KOR - \Rightarrow BRA -</u>
MYS + \nRightarrow BRA +	<u>5.655**</u>	9.542	5.627	4.498	<u>MYS + \Rightarrow BRA +</u>
MYS - \nRightarrow BRA -	<u>6.434**</u>	9.348	6.201	4.749	<u>MYS - \Rightarrow BRA -</u>
TWN + \nRightarrow BRA +	<u>4.834*</u>	9.630	6.297	4.812	<u>TWN + \Rightarrow BRA +</u>
TWN - \nRightarrow BRA -	<u>11.715***</u>	9.272	6.253	4.937	<u>TWN - \Rightarrow BRA -</u>
IND + \nRightarrow BRA +	<u>9.443***</u>	9.064	6.087	4.638	<u>IND + \Rightarrow BRA +</u>
IND - \nRightarrow BRA -	<u>6.070*</u>	9.820	6.122	4.807	<u>IND - \Rightarrow BRA -</u>

Notes: The critical values for the asymmetric causality test are calculated using a bootstrap algorithm with leverage correction. The highlighted results indicate: *the rejection of the Null Hypothesis of no causality at the 10% significance level; **the rejection of the Null Hypothesis of no causality at the 5% significance level; ***the rejection of the Null Hypothesis of no causality at the 1% significance level.

Table 7. The asymmetric Causality Test Results for Volatility, the Americas.

Null Hypothesis	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Conclusion
Canada as a recipient					
HKG + \nRightarrow CAN +	10.325**	10.533	6.536	4.800	HKG + \Rightarrow CAN +
HKG - \nRightarrow CAN -	18.713***	9.048	5.997	4.336	HKG - \Rightarrow CAN -
JPN + \nRightarrow CAN +	9.956**	10.143	5.875	4.676	JPN + \Rightarrow CAN +
JPN - \nRightarrow CAN -	28.292***	8.818	5.523	4.476	JPN - \Rightarrow CAN -
SGP + \nRightarrow CAN +	22.384***	11.136	5.854	4.601	SGP + \Rightarrow CAN +
SGP - \nRightarrow CAN -	52.514***	10.878	5.928	4.513	SGP - \Rightarrow CAN -
CHN + \nRightarrow CAN +	3.879	10.952	6.047	4.568	CHN + \nRightarrow CAN +
CHN - \nRightarrow CAN -	1.022	8.581	5.597	4.373	CHN - \nRightarrow CAN -
KOR + \nRightarrow CAN +	70.204***	8.886	6.330	4.608	KOR + \Rightarrow CAN +
KOR - \nRightarrow CAN -	40.623***	9.626	5.951	4.306	KOR - \Rightarrow CAN -
MYS + \nRightarrow CAN +	7.137**	9.949	6.279	5.040	MYS + \Rightarrow CAN +
MYS - \nRightarrow CAN -	1.893	9.053	5.805	4.417	MYS - \nRightarrow CAN -
TWN + \nRightarrow CAN +	5.747*	10.431	6.330	4.727	TWN + \Rightarrow CAN +
TWN - \nRightarrow CAN -	0.109	8.914	5.883	4.524	TWN - \nRightarrow CAN -
IND + \nRightarrow CAN +	9.402***	8.629	6.051	4.907	IND + \Rightarrow CAN +
IND - \nRightarrow CAN -	7.174**	10.745	6.215	4.666	IND - \Rightarrow CAN -
USA as a recipient					
HKG + \nRightarrow USA +	7.830*	13.407	7.912	6.235	HKG + \Rightarrow USA +
HKG - \nRightarrow USA -	25.625***	11.812	8.030	6.168	HKG - \Rightarrow USA -
JPN + \nRightarrow USA +	48.213***	17.653	10.610	8.280	JPN + \Rightarrow USA +
JPN - \nRightarrow USA -	52.316***	12.998	8.210	6.530	JPN - \Rightarrow USA -
SGP + \nRightarrow USA +	31.414***	12.919	7.955	6.196	SGP + \Rightarrow USA +
SGP - \nRightarrow USA -	60.598***	13.450	8.541	6.452	SGP - \Rightarrow USA -
CHN + \nRightarrow USA +	4.179	12.202	8.240	6.308	CHN + \nRightarrow USA +
CHN - \nRightarrow USA -	6.536*	11.871	7.902	6.367	CHN - \Rightarrow USA -
KOR + \nRightarrow USA +	87.550***	14.473	10.284	7.980	KOR + \Rightarrow USA +
KOR - \nRightarrow USA -	73.956***	13.125	7.913	6.395	KOR - \Rightarrow USA -
MYS + \nRightarrow USA +	13.385***	11.742	7.874	6.216	MYS + \Rightarrow USA +
MYS - \nRightarrow USA -	1.412	12.870	7.910	6.339	MYS - \nRightarrow USA -
TWN + \nRightarrow USA +	56.733***	12.316	9.278	7.516	TWN + \Rightarrow USA +
TWN - \nRightarrow USA -	21.105***	11.349	7.691	6.424	TWN - \Rightarrow USA -
Mexico as a recipient					
HKG + \nRightarrow MEX +	6.180**	9.727	5.965	4.809	HKG + \Rightarrow MEX +
HKG - \nRightarrow MEX -	28.587***	9.839	6.332	4.968	HKG - \Rightarrow MEX -
JPN + \nRightarrow MEX +	10.607**	11.334	7.662	5.871	JPN + \Rightarrow MEX +
JPN - \nRightarrow MEX -	22.603***	9.130	5.782	4.427	JPN - \Rightarrow MEX -
SGP + \nRightarrow MEX +	29.238***	10.643	5.646	4.463	SGP + \Rightarrow MEX +
SGP - \nRightarrow MEX -	35.952***	9.911	6.220	4.723	SGP - \Rightarrow MEX -
CHN + \nRightarrow MEX +	5.196*	10.591	6.025	4.411	CHN + \Rightarrow MEX +
CHN - \nRightarrow MEX -	9.722**	10.104	6.413	4.546	CHN - \Rightarrow MEX -
KOR + \nRightarrow MEX +	25.881***	9.824	6.152	4.729	KOR + \Rightarrow MEX +
KOR - \nRightarrow MEX -	28.260***	9.489	6.016	4.691	KOR - \Rightarrow MEX -
MYS + \nRightarrow MEX +	18.667***	8.811	6.055	4.509	MYS + \Rightarrow MEX +
MYS - \nRightarrow MEX -	6.095**	8.544	5.862	4.386	MYS - \Rightarrow MEX -
TWN + \nRightarrow MEX +	10.091**	11.695	7.985	6.184	TWN + \Rightarrow MEX +
TWN - \nRightarrow MEX -	8.222**	9.632	5.883	4.557	TWN - \Rightarrow MEX -
Brazil as a recipient					
HKG + \nRightarrow BRA +	11.063***	9.725	6.016	4.851	HKG + \Rightarrow BRA +
HKG - \nRightarrow BRA -	19.275***	9.125	6.085	4.578	HKG - \Rightarrow BRA -
JPN + \nRightarrow BRA +	31.912***	9.420	6.098	4.576	JPN + \Rightarrow BRA +
JPN - \nRightarrow BRA -	45.949***	13.572	7.404	6.198	JPN - \Rightarrow BRA -
SGP + \nRightarrow BRA +	31.541***	11.360	6.690	5.112	SGP + \Rightarrow BRA +
SGP - \nRightarrow BRA -	31.012***	9.212	6.171	4.587	SGP - \Rightarrow BRA -
CHN + \nRightarrow BRA +	3.282	9.906	6.267	4.805	CHN + \nRightarrow BRA +
CHN - \nRightarrow BRA -	3.256	8.591	5.718	4.602	CHN - \nRightarrow BRA -
KOR + \nRightarrow BRA +	23.332***	9.224	6.353	5.065	KOR + \Rightarrow BRA +
KOR - \nRightarrow BRA -	16.739***	10.246	6.108	4.576	KOR - \Rightarrow BRA -
MYS + \nRightarrow BRA +	5.393*	9.318	6.340	4.712	MYS + \Rightarrow BRA +
MYS - \nRightarrow BRA -	2.767	9.499	5.838	4.491	MYS - \nRightarrow BRA -
TWN + \nRightarrow BRA +	8.958**	10.516	6.412	4.786	TWN + \Rightarrow BRA +
TWN - \nRightarrow BRA -	4.007	10.263	6.128	4.492	TWN - \nRightarrow BRA -
IND + \nRightarrow BRA +	5.236*	10.132	6.303	4.491	IND + \Rightarrow BRA +
IND - \nRightarrow BRA -	4.492	9.869	5.963	4.806	IND - \nRightarrow BRA -

Notes: The critical values for the asymmetric causality test are calculated using a bootstrap algorithm with leverage correction. The highlighted results indicate: *the rejection of the Null Hypothesis of no causality at the 10% significance level; **the rejection of the Null Hypothesis of no causality at the 5% significance level; ***the rejection of the Null Hypothesis of no causality at the 1% significance level.

Table 8. Asymmetry in return and volatility spillovers.

Market (as recipient)	Research Hypotheses			
	Return		Volatility	
Dominant shock	H1* (- shocks)	H2** (+shocks)	H3* (- shocks)	H4** (+shocks)
Hong Kong	confirmed	rejected	rejected	confirmed
Japan	confirmed	rejected	rejected	confirmed
Singapore	rejected	rejected	rejected	confirmed
China	rejected	rejected	confirmed	rejected
Korea	rejected	rejected	rejected	confirmed
Malaysia	confirmed	rejected	rejected	confirmed
Taiwan	confirmed	rejected	rejected	confirmed
India	rejected	rejected	rejected	rejected
Germany	rejected	rejected	rejected	rejected
France	rejected	rejected	rejected	rejected
Spain	rejected	confirmed	rejected	rejected
Switzerland	rejected	rejected	rejected	rejected
Russia	rejected	rejected	confirmed	rejected
Hungary	rejected	rejected	rejected	rejected
Turkey	confirmed	rejected	rejected	rejected
South Africa	rejected	rejected	rejected	rejected
Canada	confirmed	rejected	rejected	confirmed
USA	rejected	confirmed	rejected	rejected
Mexico	rejected	rejected	rejected	rejected
Brazil	rejected	rejected	rejected	confirmed

Notes: *The Hypothesis is confirmed if, for the majority of cases, the target market is more susceptible to negative than positive shocks; **The Hypothesis is confirmed if, for the majority of cases, the target market is more susceptible to positive than negative shocks.

Figure 1. Inter-regional information transmission.

