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Testing for Global Volatility Spillover, Financial Contagion and Structural Break in Fifteen Economies from Two Regions: A Diagonal VECH Matrix and EGARCH (1,1) Approach

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Abstract

This paper studies the transmission of volatility and financial contagion among 15 countries from two regions. The extensiveness and the scope of the current paper outlines the shifting of market attributes globally, in the pre and post financial crisis period. The most significant markets in the two regions (Asia/Pacific and Europe) are studied for own-volatility spillover up to five lags and cross volatility spillover in a multivariate GARCH diagonal VECH model framework. The switch of the regional market structure is captured with "structural break" phenomenon applying partial asymmetric EGARCH that overcomes non-negativity constraints of volatility clustering. The methods combined, compare and contrast the short term variability and long term regime shifts in the two most dynamic regions of the financial world in the post global financial crisis period.

Keywords: financial contagion, volatility spillover, structural break, diagonal VECH, EGARCH

1. Introduction

In last few decades, countries of all scale experienced rapid economic growth that led to enhanced capital market activities. The degree of real linkage increased significantly and brought about the need to abolish barriers, increasing the flow of capital throughout the economies, which can be attained by complete financial liberalization; and an undeniable element of financial liberalization is financial linkage across economies. Financial linkage is crucial in a sense, with majority of economies shifting to floating exchange rate regime; better macroeconomic stabilization requires a proper degree of financial linkage (Maneschilod, 2006). While this is desirable to attain financial linkage, experts suggest stock market integration is profound in industrialized economies with high degree of financial linkage (Gultekin et al., 1989; Mittoo, 1992; Taylor and Tonks, 1989). Such financial markets integration contradicts the contemporary theories of portfolio diversification, which suggest the lack of co-movement of equity markets motivate investors to invest in foreign equity markets to diversify risk. In absence of correlated markets, the actions of market makers and investors under the circumstances of idiosyncratic shocks or stochastic volatility, outlines the behavior of emerging and emerged markets.

The US market experienced an unstoppable flow of capital due to asset scarcity in the global market, which resulted in asset bubbles. The global financial crisis commenced as in the first phase mortgage backed securities in the US market experienced a simultaneous burst in bubble. In the aftermath of mortgage market crash many of the other alternative saving vehicles followed and the exacerbation of crisis resulted in the shortage of assets in the world economy. The massive upheaval in the US asset market eventually triggered scarcity in alternative vehicles through contingent and non-contingent channels, and recreated bubble in commodities such as oil markets. The increasing oil prices turned financial assets seeking petrodollar to the US market, and thus influenced stabilization, reducing destabilization caused by capital outflows. In the second phase, when the global growth fell steep, the deceleration of growth, in course of time reversed the tighten of commodity prices. Such resulted in reversion of bubble construction and destroyed bubble formation in commodities that commenced in the summer of 2008. The vicious cycle therefore, adjusted the economic bubble, leaving behind many partially and non-contingent economies in rubbles (Caballero et al. 2013).

Many studies examined the characteristics of recent episodes of local stock market "shocks" in non-contingent markets such as Mexico(1982), Russia (1998), Brazil (1999), Thailand (1997), resulting from initiation of the process of abolishing the capital control by the host countries. The propagation of shock into uncorrelated markets spiked the interest of experts to apply new methods in non-contingent markets to examine the spread and aftermath of shocks. While emerging markets, with less financial linkages, surprised the experts with indication to shocks propelling from "ground zero" economy and spreading into economies, correlated to a lesser extent, the risks of financial linkage is enhanced. Arshanapalli and Doukas (1993) outlined that the 1987 stock market crash, fortified the stock market integration among the emerged economies. In addition, during Exchange Rate Mechanism Crisis of 1992-93, East Asian Crisis of 1997 and Russian Crisis of 1998 bears evidence of financial markets increased integration post-financial crisis (Chan Lau et al 2004). From the analysis of 1990s tech bubble by Chan Lau and Ivaschenko (2001), it is suggested that in bull markets, price synchronism intensifies. Bassler and Yang (2003) suggested in response, that such integration decreases the benefit of diversification, as the integrated markets offer little benefits if the market movements are parallel. Though during such propagation of shocks, mutual funds are preferred investment vehicle (Bhattacharyya and Nanda,1999), the role of mutual funds are largely scrutinized by Brown, Goetzmann and Park (1998); Eichengreen and Mathieson (1998); Kaminsky, Lyons and Schmuklar (2000,2001); Disyatat and Gelos (2001); Kim and Wei (2002). Previous studies focused on the stock market co-movement in the framework of local market turbulences and global crisis up to 2002, while the recent financial crisis of 2007 have altered the market relationships and behavior of number of markets to a great extent.

Collins and Biekpe (2003) defined the risk of "contagion" as the wider integration of equity markets, which may cause reversals in the international capital movement due to an enhanced level of foreign influence. The US mortgage market crash, resulting from integrated securitization is undoubtedly the recent most significant example of financial contagion in the literature of financial linkage. "Contagion" has been used largely in medicine, sociology and philosophy, bearing the meaning " transmission by direct or indirect contact; the spread of a behavior pattern, attitude, or emotion from person to person or group to group through suggestion, propaganda, rumor or imitation; the tendency to spread, as of doctrine, influence or emotional". The impact of financial contagion intrigued researchers during the Asian crisis. The shocks may propagate through crisis non-contingent and crisis contingent channels. "Monsoonal effect" of financial contagion is as described by Masson (1999) the contamination of stock market contagion among countries with similar macroeconomic policies. Crisis non-contingent channel contagion may spread trade links and financial links as well. Following a stock collapse in "ground zero" economy, investors tend to sell off assets to rebalance portfolio, and shocks propel through markets, resulting from market behavior rather than local turmoil; where the portfolio rebalancing is amplified by information asymmetry (Calvo, 1999). Crisis contingent channel propagation of contagion is best categorized by "shift contagion" and "pure contagion." "Shift contagion illustrates the propagation of shock beyond normal level"; during a crisis, while "pure contagion" is the transmission of contagion purely due to unexplained fundamentals generally identified post crisis period (Percolli and Sbracia, 2003; Dungey and Tambakis, 2005; Flavin and Panopoulou, 2010). Majority of the transition and non-transition economies are inflicted as volatility spillovers take place, causing reversals in the market confidence (Charumilind et al. 2006). In addition to financial linkage, real linkage plays an important role in integrating stock markets in different contingents. Real linkage or integration of economic fundamentals may give birth to idiosyncratic shocks, which alter market behavior more extensively after a crisis, contrasting to behavior prior to the crisis. In an example of the propagation of shocks caused by real linkage, let us assume there is private information to a market maker in the host country of an idiosyncratic shock. Now, to conceal the fact that the market maker takes his next move from the private information from dealer, or to protect a market from speculative attack, the market maker sells an asset of the host country, and a foreign asset, in order to rebalance portfolio. Speculators may also believe that the market makers actions are shaped by systematic information. A pool of such behavior propelled by asymmetric information causes contamination or can better be explained with volatility spillover into uncorrelated markets. Spillover of volatility intensifies in the presence of a crisis, which is better explained by capturing structural break in the system, and such behavior has been discussed profoundly in a number of empirical literatures. To be able to examine this phenomenon in the financially globalized markets, it is also important to illustrate the historic attributes of different markets around the world.

In the study conducted by Khallouli and Sendretto (2012), the accession of US market into some Middle Eastern and North African Muslim countries have been checked, which can be considered as one of the recent works in this class. The study on MENA countries reveal that US subprime crisis raises the probability of many markets in the region to shift from high-mean, low-variance to low-mean, high variance region. The study applied markov-switching model to trace the fixed transition probability of time varying relationship of risk and return. The experts suggested from the finding that the segmented MENA equity markets were less immune to the risk of contagion and questioned the efficiency of international portfolio diversification in this part of the world. A study by Maneschiold (2006), checked long run, steady-state integration among Baltic stock markets and International Stock markets, using bidirectional causality, suggested the existence of low correlation with international turmoil. It was argued that these markets are less dependent on investment horizon and a greater benefit can be achieved in portfolio diversification; in spite of the markets having trace of local contagion compared to global volatility contagion. Similar study conducted by Gunduz and Hatemi-J (2005), applying similar causality among Hungary, Poland, Czech Republic examined with significant uni-directional and bi-directional causality, but such are less significant between Russia and Turkey. However, as Russia and Turkey in such case are immune to contagion effect, the researchers directed their focus on the weak-form of information efficiency between these two large-scale traders. While Southeast Asian economy has been envy to many economies, a relatively old study by Chancharoenchai and Dibooglu (2006) examined six Southeast Asian markets seeking volatility spillover effect and found strong evidence of relationship in 1997 Asian crisis framework. The significance of interaction reveals the degree of openness in these markets, while markets were left vulnerable to foreign shocks transmitted through real linkage.

There has been plethora of studies conducted in contradiction to popular belief relating to volatility contagion. The existing theories are categorized broadly into real linkage models and financial linkage models. *Real linkage* emphasizes on the propagation of shock through trade linkage and shocks are mostly idiosyncratic in nature (Helpman and Razin, 1978; Cole and Obstfeld, 1991; Backus, Kehoe and Kydland, 1992; Baxter and Crucini, 1993; Case and Pavlova, 2004). Most of these studies attempted to rationalize spillover effects in the presence of low correlations of fundamentals. However, empirical evidence are relatively unsupportive but abundant in this regard (Kaminsky and Reinhart, 2000; Mody and Teylor, 2002). Not only these studies failed to explain the causes for crisis to spread in East Asia, Latin America and Eastern Europe but also the reasons for financial crisis not to contaminate the neighboring countries despite of the existence of significant real linkages. The second branch of studies shifted the concentration to *financial linkage* in contagion. The dispute around the first *correlated information* channel introduced by King and Wadhwani (1990) which elaborates discussion on contamination of asymmetric information is spiked by *portfolio rebalancing* discussed largely in the studies of Fleming, Kirby and Ostdiek (1998). The later demonstrates the reactions of risk averse investors to private information, which may mislead the updating process of information. While it is believed that information is shared symmetrically among the markets, most volatile markets are characterized by information heterogeneity. In trace of eminent idiosyncratic shocks, strategic traders are endowed more with diverse information that leads to the transmission of contagion of volatility. Therefore, the impact of regime shifting is important to study in the field contagion and spillover study.

An important study conducted by Yuan (2005) outlined interesting attributes of financial contagion. Through the construction of rational expectations equilibrium (REE), Yuan suggested contagion and financial crisis opt to appear following a small shock, resulting in a large movement of assets, mostly towards negative direction. In markets of acute information asymmetry, if the condition of borrowing constraints exist, financial crisis is more likely. It can therefore, be suggested that contagion is mostly asymmetrical and asset prices in contagion prone economies are more skewed (Connolly and Wang, 2003). In contradiction to previous studies, Yuan (2005) proved through REE, that crisis is consequence not of common shocks but of investors borrowing constraints. Such constraints help crisis to propagate in economies through same group of investors during financial upheavals.

The current study examines global financial contagion and volatility transmission, with focus to the post financial crisis 2007 period. As observed from the previous section, most of the papers examined the spillover effect and contagion effect on sample markets ranging from specific markets to specific regions. While some of the previously conducted papers checked for market linkage applying cointegration and focused on stationary condition of stock index, this paper focuses on "leverage effect" and "volatility clustering" property of short term non-linear market data and tests the attributes of conditional variability of global financial market. The financial crisis of 2007 is responsible for altering financial markets across countries, and thus, this paper studies the transmission of volatility and financial contagion among 15 countries from two regions, with and without linkage to the US market (US accession). The extensiveness and the scope of the current paper outlines the shifting of market attributes globally, in the pre and post financial crisis period. The most significant markets in the two regions (Asia/Pacific and Europe) are studied for own-volatility spillover up to five lags and cross volatility spillover in a multivariate GARCH diagonal VECH model framework. The switch of the regional market structure is captured with "structural break" phenomenon applying partial asymmetric EGARCH that overcomes non-negativity constraints of volatility clustering. The methods combined, compare and contrast the short term variability and long term regime shifts in the two most dynamic regions of the financial world is the post global financial crisis period.

2. Empirical Framework

To investigate the behavior of excess return volatility and volatility spillovers we consider the weekly stock prices of eight major Asia-Pacific Markets (India, Japan, China, South Korea, Taiwan, Malaysia, Singapore and Australia) for the Asia-pacific region and for the European region we consider seven major markets (Austria, France, Germany, Greece, Netherlands, Italy and United Kingdom) of Europe. The sample economies are selected on the basis of the probability of the markets being less homogeneous to each other. It must be noted that, in Asia/Pacific and in Europe some major economies are skipped because it seems, in the post-financial crisis period some of the contemporary major economies are reciprocal in nature, as the association increases among the market anomalies. Such a major economy in the European region would be Spain. Regardless of Spain being the fourth biggest economy in Europe, the financial crisis and the subsequent Eurozone crisis sends Spanish market tumbling as it does for Greece and for Italy (Castle and Jolly, 2012). To avoid such reciprocation, we consider the sample economies that should be more heterogeneous to each other. It is better to consider smaller economies, as they are believed to be more heterogeneous. The sample therefore emphasizes on structural dissimilarities of the markets as that would be more interesting to check for association among markets more divergent.

Weekly data offer some advantages over the use of daily data. Firstly, it evades the interferences linked with the use of corresponding data as the trading day of one country may overlap with a public holiday in another country. Secondly, it also circumvents the time zone differences. We collect the data over the period 8/11/1997 to 4/02/2013 and include 797 observations. For examining the impact of global financial shock, we consider US stock market index as the "ground zero" host market and used it as an exogenous shock. Weekly returns of the stock indices has been converted into logarithmic term where the series of observed returns converted into squared weekly returns which in fact gives the volatility estimate for each point in time (t). The range of the approximation has been calculated by taking the log of the ratio of the highest observed price to the lowest observed price for each weekly return at time (*t*),

$$\sigma_t^2 = \log\left(\frac{High_t}{Low_t}\right)$$

In this paper, we form the joint process of prevailing stock market return indices for both Asia-Pacific and European region using the Multivariate GARCH-Diagonal VECH model. The conditional variance-covariance equations for the unbounded VECH model contain 21 parameters. The VECH model's conditional variance-covariance matrix has been bound to the form developed by, Bollerslev, Engle and Wooldridge (1988), where, *A* and *B* are assumed to be diagonal. The VECH model characterized by,

$$h_{ij,t} = \omega_{ij} + \alpha_{ij} u_{i,t-1} u_{j,t-1} + \beta_{ij} h_{ij,t-1} \quad \text{for } i, j = 1, 2 \tag{1}$$

In equation (1), ω_{ij}, α_{ij} and β_{ij} are the parameters. The diagonal VECH multivariate GARCH model could also be articulated as an unbound order multivariate ARCH model, where the covariance is represented as a geometrically dilapidated weighted average of precedent cross products of unanticipated returns, with recent observations carrying higher weights.

The conditional variance-covariance matrix (H_t) has eight (i.e. for Asia-Pacific region), seven (i.e. for Europe region) dimensions with the diagonal, and non-diagonal components stand for the variance and the covariance stipulations, correspondingly. H_t can be expressed in the matrix form,

$$H_t = \begin{pmatrix} h_{11t} & h_{12t} & \cdots & \cdots & h_{18t} \\ h_{21t} & . & \cdots & \cdots & h_{28t} \\ \vdots & . & . & . & \vdots \\ \vdots & . & . & . & \vdots \\ h_{81t} & h_{82t} & \cdots & \cdots & h_{88t} \end{pmatrix} \tag{2}$$

In this matrix h_{ijt} is a conditional variance at the point of time *t* for the stock return of country *i* and refers to the conditional covariance linking the stock returns of country *i* and country *j* ($i \neq j$) at time *t*.

We used the diagonal VECH model (Bollerslev et al., 1988) to enhance the understanding of the conditional variance and covariance matrix since this model is more flexible when we use more than two variables (Scherrer and Ribarits, 2007). The diagonal VECH demonstration works, based on the theory that the conditional variance depends on squared lagged residuals and the conditional covariance depends on the cross-lagged residuals and lagged covariance of other series (Harris and Sollis, 2003). The diagonal VECH model can also characterized by,

$$VECH\ (H_t) = C + AVECH\ (\varepsilon_{t-1}\varepsilon'_{t-1}) + BVECH\ (H_{t-1}).\ e_t|\psi_{t-1} \sim N\ (0,\ H_t) \quad (3)$$

Where, A and B are 1/2 N (N +1) × 1/2 N (N +1) parameter matrices and C is a 1/2 N (N +1) ×1 vector of constants. The diagonal elements of matrix A (a_{11}, a_{22}, ⋯ ⋯ a_{88}) deals with the influence from previous squared innovations on the present explosive nature, which can also be expressed as own volatility shocks. On the other hand, non-diagonal essentials verify the cross product consequences of the lagged innovations on the cross-volatility shocks. In the same way, the diagonal elements of matrix B (b_{11}, b_{22}, ⋯ ⋯ b_{88}) provide the impacts from past squared volatilities on the current volatility which can be expressed as own volatility spillovers and non-diagonal elements determine the cross product effects of the lagged cross-volatilities on the cross-volatility spillovers.

Because of the non-negativity clause of the traditional GARCH (1,1) model, we follow the partial asymmetric GARCH model called EGARCH created by Nelson(1991) to detect the volatility clustering and leverage effect impact within these elected stock markets. The model measurements is given below,

$$\mathrm{Ln}\sigma^2_{j,t} = \omega_j + \beta_j \ln(\sigma^2_{j,t-1}) + \gamma\frac{\varepsilon_{t-1}}{\sqrt{\sigma^2_{t-1}}} + \alpha\left[\frac{|\varepsilon_{t-1}|}{\sqrt{\sigma^2_{t-1}}} - \sqrt{\frac{2}{\pi}}\right] \quad (4)$$

$\sigma^2_{j,t}$ is one step forward estimate of variance also known as conditional variance, and $\omega,\beta,\gamma,\alpha$ are the parameters to be projected. The benefit of using EGARCH (1,1) model is that even if the parameters are negative, σ^2_t will always be positive. In equation (4) parameter α correspond to the symmetric effect of the model, β represents volatility persistence and γ denotes the leverage effects (Alexander, 2009).

3. Empirical Results

Table 1, presents the descriptive statistics for all the stock market indices along with the global market proxy US. The mean returns for all the stock indices are positive, array from a minimum 0.0005 (both China and Italy) to a maximum 0.1699 (Austria). According to the sample standard deviations, Australian stock return is the least volatile series with a standard deviation of 0.0077, while the stock return of South Korea could be considered as the most volatile series with a standard deviation of 0.0155. The first column of the table 1 represents the cross-correlation between Asia-pacific and Europe region with US stock indices. The correlation coefficients of Asia-Pacific region and US market seem excessively low compared to the Europe region. In Asia-Pacific, the highest correlation is with Australia (0.7716) and the lowest is with Malaysia (0.0915) indicating the level of interdependence between US market and Asian market is comparatively low. On the other hand, For Europe region, highest correlation of US market is with Austria (0.7979) and the lowest is with Greece (0.3660). For other markets of this region, correlation is more than .60 for all cases.

Table 1. Descriptive statistics for all stock indices

	Correlation	Mean	Median	Std. Dev.	Skewness	Kurtosis	J-B
TAIWAN	0.1965	0.0196	0.0171	0.0109	1.6727	7.33	993.45***
SINGAPORE	0.4160	0.0172	0.0141	0.0124	2.9342	16.58	7262.98***
SOUTH KOREA	0.2957	0.0239	0.0197	0.0155	1.9512	8.61	1549.77***
MALAYSIA	0.0915	0.0150	0.0108	0.0146	3.9360	26.26	20003.05***
JAPAN	0.4029	0.0182	0.0162	0.0105	3.6839	29.05	24312.53***
INDIA	0.4485	0.0214	0.0184	0.0125	2.1611	10.58	2526.52***
CHINA	0.2331	0.0129	0.0107	0.0084	1.6221	6.49	752.55***
AUSTRALIA	0.7716	0.0118	0.0098	0.0077	2.8177	15.85	6533.11***
UNITED KINGDOM	0.7644	0.0162	0.0137	0.0102	2.6376	16.17	6681.03***
NETHERLANDS	0.6065	0.0137	0.0112	0.0099	2.1806	10.34	2419.33***
ITALY	0.6325	0.0130	0.0104	0.0094	1.9492	8.61	1548.71***
GRECE	0.3660	0.0162	0.0132	0.0118	2.1387	10.06	2261.15***
GERMANY	0.6368	0.0209	0.0174	0.0132	2.2485	10.66	2621.40***
FRANCE	0.7196	0.0196	0.0168	0.0118	2.0798	10.23	2308.21***
AUSTRIA	0.7979	0.0184	0.0149	0.0137	3.8538	29.19	24749.86***
USA	-	0.0135	0.0106	0.0105	3.7017	26.50	20131.5***

Note: *** indicating 1% level of significance.

Based on the estimated skewness statistics, all indices skewed to right. As expected with any high frequency financial return series, the assessment of kurtosis is more than three for all the countries. Which represent a classic leptokurtic distribution, whereby the series are spikier around the mean with a thicker tails compared to the normal distribution. In addition, outcome of the J-B test shows that the null hypothesis of normal distribution at 1% level of significance is rejected for all stock markets indices.

In order to evaluate the fitness of the model, Autoregressive Conditionally Heteroskedasticity – ARCH (1,1) tests were conducted on the standardized and squared residuals and the end results were satisfactory. The outcomes satisfy the stipulation of non-linearity. The outcome of the ARCH test (up to 5 lags) implies significance in the non-linearity of the observations.

Table 2. ARCH (1,1) results for Asia-Pacific region

	India	Japan	China	Malaysia	Taiwan	South Korea	Singapore	Australia
F-statistic	15.40***	7.67***	3.07***	12.71***	3.14***	19.80***	21.82***	6.71***
Obs*R^2 (χ^2)	70.68***	36.84***	15.19***	59.26***	15.52***	88.60***	96.54***	32.42***
u_{t-1}	0.257***	0.057*	0.107***	0.153***	0.132***	0.200***	0.210***	0.143
u_{t-2}	0.024	0.063*	0.031	0.041	-0.019	0.175***	0.079**	0.049
u_{t-3}	0.092**	0.190***	0.040	0.145***	0.021	0.079**	0.076**	0.081**
u_{t-4}	0.016	-0.005	0.022	0.094***	0.029	-0.009	0.190***	-0.002
u_{t-5}	0.009	-0.015	0.040	-0.013	0.020	0.004	-0.083**	0.057*

Notes: *** 1%, ** 5%,* 10% level of significance.

Table 3. ARCH (1,1) results for Europe region

	Austria	France	Germany	Greece	Italy	Netherlands	United Kingdom
F-statistic	2.032*	2.555**	2-953**	6.575***	10.688***	7.782***	3.651***
Obs*R^2 (χ^2)	10.111*	12.667**	14.607**	31.798***	50.418***	37.35***	17.979***
u_{t-1}	0.030	0.075**	0.038	0.161***	0.156***	0.166***	0.031
u_{t-2}	-0.007	0.003	0.054	0.054	0.070**	-0.001	0.008
u_{t-3}	0.081**	0.034	0.078**	0.020	0.136***	0.123***	0.103***
u_{t-4}	0.017	0.070**	0.070**	0.009	0.023	-0.016	0.093***
u_{t-5}	0.067**	0.044	0.007	0.064**	-0.011	0.049	0.012

Notes: *** 1%, ** 5%,* 10% level of significance.

The results reported in table 4 (Asia-Pacific) and 6 (Europe) represents values of the own mean spillovers (μ_{ii} for all i= 1,..,8 and i= 1,..,7) are significant at the 1% per cent level of significance, providing evidence of an influence on current returns of each stock market arising from their first lag returns (r_{iit-1}). For Asia-Pacific region the own-mean spillovers fluctuate from a smallest amount of 0.0046 (Australia) to the highest of 0.0094 (Taiwan). Positive cross-mean spillovers consequence is present from in between countries of experiment. Within the Asia-Pacific region, there is no negative cross mean spillovers and the impact of cross mean spillover is significant in both directions.

Table 4. Parameter estimation for the mean equation from diagonal VECH (1,1) equation for Asia-Pacific

Parameter		μ_{0i}	μ_{i1}	μ_{i2}	μ_{i3}	μ_{i4}	μ_{i5}	μ_{i6}	μ_{i7}	μ_{i8}
Australia	**Coef.**	0.0093***	0.0046	0.0094	0.0066	0.0075	0.0106	0.0088	0.008	0.0093
	S.E.	0.00018	0.00039	0.00049	0.0005	0.00052	0.00039	0.00049	0.00044	0.00055
China	**Coef.**	0.0106***	0.0101	0.0083	0.0104	0.0109	0.0122	0.0116	0.0108	0.0116
	S.E.	0.00046	0.00053	0.00051	0.00059	0.00059	0.00043	0.00055	0.0005	0.00062
India	**Coef.**	0.0177***	0.0139	0.0179	0.0084	0.0149	0.019	0.0144	0.0148	0.0154
	S.E.	0.00036	0.00073	0.00079	0.0007	0.00084	0.00062	0.00076	0.0007	0.00088
Japan	**Coef.**	0.0162***	0.0105	0.0159	0.0105	0.0093	0.0154	0.0108	0.0109	0.0125
	S.E.	0.00061	0.00059	0.00067	0.00066	0.00065	0.00051	0.00061	0.00055	0.00073
Malaysia	**Coef.**	0.01056***	0.01105	0.01426	0.00966	0.01019	0.00669	0.00645	0.00638	0.00996
	S.E.	0.00046	0.00092	0.00095	0.001	0.00102	0.00062	0.00088	0.0008	0.00105
South Korea	**Coef.**	0.0161***	0.0169	0.0226	0.0135	0.0149	0.017	0.0084	0.0134	0.0147
	S.E.	0.00034	0.00094	0.001	0.001	0.00103	0.00071	0.00077	0.00082	0.00107
Singapore	**Coef.**	0.0124***	0.0087	0.0139	0.0083	0.0081	0.0124	0.0082	0.0069	0.0105
	S.E.	0.00026	0.00071	0.00079	0.00079	0.0008	0.00059	0.00072	0.00061	0.00087
Taiwan	**Coef.**	0.0163***	0.0155	0.0183	0.015	0.0134	0.0169	0.0131	0.0143	0.0094
	S.E.	0.00048	0.00067	0.0007	0.00074	0.0007	0.00053	0.00065	0.00061	0.00068

Notes: (1) i = 1 for Australia, i = 2 for China, i = 3 for India, i = 4 for Japan, i = 5 for Malaysia, i = 6 for South Korea, i = 7 for Singapore, i = 8 for Taiwan. (2)*** 1%, ** 5%,* 10% level of significance. (3) From $\mu_{i1} - \mu_{i8}$ all coefficients are statistically significant at 1% level of significance.

Table 5. Parameter estimation for the variance equation from diagonal VECH (1,1) equation for Asia-Pacific

Parameter		C_{i1}	C_{i2}	C_{i3}	C_{i4}	C_{i5}	C_{i6}	C_{i7}	C_{i8}
Australia	**Coef.**	0.0000013	-0.0000027	0.0000051	0.0000018	0.0000050	0.0000041	0.0000016	.0000010
	S.E.	0.0000043	0.0000032	0.0000048	0.0000369	0.0000046	0.0000176	0.0000108	.0000124
China	**Coef.**		0.0000134*	-0.0000006	-0.0000013	-0.0000017	0.0000027	0.0000005	-.0000012
	S.E.		0.0000074	0.0000035	0.0000173	0.0000033	0.0000092	0.0000058	.0000044
India	**Coef.**			0.0000299***	0.0000032	0.0000073*	0.0000057	0.0000046	.0000074
	S.E.			0.0000101	0.0000724	0.0000041	0.0000253	0.0000177	.0000318
Japan	**Coef.**				0.0000201***	0.0000044	0.0000015	0.0000031	.0000037
	S.E.				0.0000063	0.0000415	0.0000198	0.0000126	.0000154
Malaysia	**Coef.**					0.0000168**	0.0000013	0.0000015	.0000046
	S.E.					0.0000069	0.0000120	0.0000079	.0000160
South Korea	**Coef.**						0.0000050	0.0000019	.0000059
	S.E.						0.0000107	0.0000060	.0000102
Singapore	**Coef.**							0.0000017	.0000026
	S.E.							0.0000032	.0000029
Taiwan	**Coef.**								.0000119
	S.E.								.0000084
Parameter		a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}	a_{i6}	a_{i7}	a_{i8}
Australia	**Coef.**	0.2976***	0.2409	0.3213***	0.1917	0.2807**	0.2608	0.1924	0.2215*
	S.E.	0.0976	0.4237	0.0641	0.6842	0.1115	0.1617	0.1321	0.1297
China	**Coef.**		0.2598*	0.2110	0.1569	0.2358**	0.2004*	0.1131*	0.1912
	S.E.		0.1426	0.2394	1.6828	0.0998	0.1076	0.0588	0.2552
India	**Coef.**			0.3536***	0.1735	0.3296***	0.2869***	0.1990***	0.2496
	S.E.			0.1162	1.4154	0.0794	0.0465	0.0620	0.1899
Japan	**Coef.**				0.1558	0.1828	0.1849	0.1299	0.1594
	S.E.				1.0473	0.7973	0.8293	0.5775	0.6528
Malaysia	**Coef.**					0.3801***	0.2697***	0.1956***	0.2453
	S.E.					0.1167	0.0656	0.0549	0.1984
South Korea	**Coef.**						0.2808**	0.1708	0.1885**
	S.E.						0.1432	0.1647	0.0784
Singapore	**Coef.**							0.1267	0.1756
	S.E.							0.1911	0.2015
Taiwan	**Coef.**								0.2311**
	S.E.								0.102
Parameter		b_{i1}	b_{i2}	b_{i3}	b_{i4}	b_{i5}	b_{i6}	b_{i7}	b_{i8}
Australia	**Coef.**	0.2416*	0.3166	0.2920***	0.2986	0.3008	0.3586	0.4280	0.3224
	S.E.	0.1250	0.8587	0.1115	3.5283	0.4813	0.2389	0.2786	0.3262
China	**Coef.**		0.5067***	0.4635	0.4777	0.4982***	0.5096	0.6276	0.4791
	S.E.		0.1112	0.3589	3.6405	0.1804	0.5222	0.7320	0.2689
India	**Coef.**			0.4045***	0.4205	0.4780***	0.4574***	0.5689***	0.4227
	S.E.			0.0795	4.0029	0.0547	0.0883	0.0848	0.3970
Japan	**Coef.**				0.5774	0.5282	0.5918	0.6656	0.5767
	S.E.				2.1075	2.2423	0.9818	0.9899	1.9361
Malaysia	**Coef.**					0.5576***	0.5755***	0.6656***	0.5313
	S.E.					0.0713	0.0987	0.0652	0.3284
South Korea	**Coef.**						0.7018***	0.7309***	0.5580***
	S.E.						0.0572	0.0966	0.1340
Singapore	**Coef.**							0.8296***	0.6314***
	S.E.							0.1480	0.1067
Taiwan	**Coef.**								0.5612***
	S.E.								0.2062

Notes: (1) i = 1 for Australia, i = 2 for China, i = 3 for India, i = 4 for Japan, i = 5 for Malaysia, i = 6 for South Korea, i = 7 for Singapore, i = 8 for Taiwan. (2)*** 1%, ** 5%,* 10% level of significance.

Table 6. Parameter estimation for the mean equation from diagonal VECH (1,1) equation for Europe

Parameter		μ_{0i}	μ_{i1}	μ_{i2}	μ_{i3}	μ_{i4}	μ_{i5}	μ_{i6}	μ_{i7}
Austria	**Coef.**	0.01574***	0.005682	0.007477	0.009867	0.012607	0.010021	0.010777	0.007378
	S.E.	0.001372	0.000589	0.000833	0.000836	0.000786	0.000745	0.000763	0.000788
France	**Coef.**	0.01756***	0.01186	0.00644	0.007581	0.015339	0.010771	0.009941	0.007274
	S.E.	0.00104	0.000608	0.000602	0.000593	0.000683	0.000597	0.000575	0.000587
Germany	**Coef.**	0.01886***	0.013078	0.006001	0.006488	0.016289	0.01158	0.009912	0.007279
	S.E.	0.001268	0.000705	0.000675	0.000636	0.000771	0.000689	0.000644	0.000671
Greece	**Coef.**	0.01461***	0.010543	0.0106	0.011927	0.009175	0.010796	0.01203	0.010456
	S.E.	0.001062	0.000654	0.000781	0.000761	0.00064	0.000674	0.000693	0.000748
Italy	**Coef.**	0.01134***	0.007309	0.004467	0.005453	0.00879	0.005723	0.006765	0.005276
	S.E.	0.00082	0.000498	0.000545	0.000537	0.000535	0.000472	0.000502	0.000536
Netherlands	**Coef.**	0.01156***	0.006223	0.000119	0.001651	0.008643	0.003905	0.005585	0.001713
	S.E.	0.001552	0.000483	0.000386	0.000415	0.000551	0.000416	0.000483	0.000423
United Kingdom	**Coef.**	0.01455***	0.008994	0.004956	0.006181	0.01221	0.008806	0.008185	0.005277
	S.E.	0.000779	0.000516	0.000531	0.000531	0.00059	0.000527	0.000512	0.000503

Notes: (1) i = 1 for Austria, i = 2 for France, i = 3 for Germany, i = 4 for Greece, i = 5 for Italy, i = 6 for Netherlands, i = 7 for United Kingdom. (2)*** 1%, ** 5%,* 10% level of significance. (3) From μ_{i1} – μ_{i7} all coefficients are statistically significant at 1% level of significance.

In case of European region (table 6), the own-mean spillovers are also significant at 1% level of significance. The own-mean spillovers vary from a largest 0.015741 (Austria) to a smallest 0.003905 (Netherlands). All cross mean spillovers are positive and significant indicating that the impact of cross mean spillovers exists in both directions.

In table 5, the own-volatility distress for all eight markets (a_{11}, a_{22} . . . a_{88}) are significant except for Japan and Singapore and fluctuates from 0.231093 (Taiwan) to 0.380093 (Malaysia), demonstrating the existence of ARCH effects. This indicates that the precedent shocks occurring from the Malaysian market will have the strongest impact on its own future market volatility compared to the shocks stemming from the other markets. Based on the magnitudes of the estimated cross-volatility coefficients, $a_{ij}(i \neq j)$, innovation in all of the eight stock indices maneuver the instability of other indices, but the own-volatility shocks, a_{ij} ($i = j$), are normally bigger than the cross-volatility shocks. This recommends that past volatility shocks in individual markets have a larger effect on their own future unpredictability than past volatility shocks occurring from other indices. Therefore, it become visible that the lagged country-specific shocks (ARCH influence) do add to the stock market volatility of any given country in a recursive way.

Unlike the Asia-Pacific region, European region (Table 7) shows a different result for own volatility shocks (a_{11}, a_{22} . . . a_{77}). There is significant result for only three stock indices (France, Italy and United Kingdom) and varies from 0.422786 (United Kingdom) to 0.343712 (France). These results of European region indicate that these countries (except France, Italy, and United Kingdom) have strong exogenous impact on their future market volatility rather than the shocks generating from their own market.

In European region, the degree of cross-volatility shock is strongest between France and United Kingdom (0.401234) and the weakest is between Germany and Italy (0.338840). For Asia-Pacific region the strongest cross-volatility shock exist in between India and Malaysia (0.3296) and the weakest is in between China and Singapore (0.1131).

The projected coefficient for the variance-covariance matrix (equation 3) is also presented in Table 5(Asia-Pacific) and Table 7 (Europe). With $b_{ij}(i \neq j)$ one-lag conditional variance for both Asia-Pacific and Europe region are positive but most of them are not significant. Compared to Europe, the Asia-Pacific region has higher significant values, which indicates the presence of high volatility persistence. In Asia-Pacific region the largest value for the own volatility impact belongs to Singapore (0.8296) and the lowest belongs to Australia (0.2416). These results imply that these markets have the strongest impact on their future volatility from their own past volatility. On the other hand, Europe region does not have any significant values for one-lag conditional variance, indicating very low volatility persistence.

Table 7. Parameter estimation for the variance equation from diagonal VECH (1,1) equation for Europe

Parameter		C_{i1}	C_{i2}	C_{i3}	C_{i4}	C_{i5}	C_{i6}	C_{i7}
Austria	**Coef.**	0.0000568	0.00000633	0.000002	0.0000106	0.00000815	0.00000622	0.00000726
	S.E.	0.000235	0.000139	0.000213	0.000134	0.000126	0.000133	0.00012
France	**Coef.**		0.00000836	0.0000027	0.00000247	0.00000648	0.00000127	0.00000625
	S.E.		0.0000388	0.00012	0.0000959	0.0000772	0.0000632	0.0000454
Germany	**Coef.**			0.00000406	0.000000191	0.0000022	-6.71E-08	0.00000307
	S.E.			0.000219	0.00015	0.00017	0.0000667	0.000101
Greece	**Coef.**				0.0000371	0.0000041	0.00000123	0.00000486
	S.E.				0.000107	0.000109	0.0000912	0.0000864
Italy	**Coef.**					0.0000185	0.00000178	0.00000505
	S.E.					0.0001	0.0000448	0.000061
Netherlands	**Coef.**						0.0000132	0.0000016
	S.E.						0.000111	0.0000654
United Kingdom	**Coef.**							0.0000121
	S.E.							0.0000472
Parameter		a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}	a_{i6}	a_{i7}
Austria	**Coef.**	0.417582	0.398416	0.373629	0.264258	0.3788	0.385364	0.419757
	S.E.	0.721572	0.294703	0.571996	0.230525	0.432623	0.612468	0.363071
France	**Coef.**		0.379674*	0.356085	0.250186	0.359832***	0.369283*	0.401234**
	S.E.		0.232068	0.17545	0.354527	0.084145	0.192779	0.190825
Germany	**Coef.**			0.334284	0.23474	0.338840*	0.346066	0.376149
	S.E.			0.273942	0.543303	0.204165	0.489955	0.262895
Greece	**Coef.**				0.171082	0.236524	0.239498	0.264826
	S.E.				0.229973	0.344684	0.190586	0.267515
Italy	**Coef.**					0.343712***	0.351193	0.381679***
	S.E.					0.11372	0.282878	0.129485
Netherlands	**Coef.**						0.360248	0.389767
	S.E.						0.595646	0.328643
United Kingdom	**Coef.**							0.422786**
	S.E.							0.179631
Parameter		b_{i1}	b_{i2}	b_{i3}	b_{i4}	b_{i5}	b_{i6}	b_{i7}
Austria	**Coef.**	0.004474	0.019296	0.020545	0.019925	0.015055	0.019062	0.013783
	S.E.	0.299964	0.34672	0.417481	0.497609	0.398662	0.438666	0.435084
France	**Coef.**		0.428564	0.469508	0.464067	0.336243**	0.349575	0.294463
	S.E.		0.284036	0.300014	0.48806	0.167526	0.452881	0.391218
Germany	**Coef.**			0.531372	0.517937	0.38563	0.391604	0.330329
	S.E.			0.423703	0.411551	0.26081	0.568057	0.331902
Greece	**Coef.**				0.510469	0.373566**	0.385254	0.320035
	S.E.				0.39017	0.183605	0.260124	0.642087
Italy	**Coef.**					0.280512	0.278038	0.238073
	S.E.					0.225179	0.342261	0.269303
Netherlands	**Coef.**						0.293081	0.2405
	S.E.						0.635203	0.430398
United Kingdom	**Coef.**							0.206262
	S.E.							0.486231

Notes: (1) i = 1 for Austria, i = 2 for France, i = 3 for Germany, i = 4 for Greece, i = 5 for Italy, i = 6 for Netherlands, i = 7 for United Kingdom. (2)*** 1%, ** 5%,* 10% level of significance.

The level of variability of the stock indices before and after/within the financial crisis of 2007 capturing structural break property of switch model is presented in table 8 (for Asia-Pacific region) and table 9 (for Europe region). The student-t EGARCH (1,1) model was used to estimate the parameters. The first part of both tables present the variability of the overall sampling period and the remaining parts show the pre (i.e. 30th June, 1997 to 25th December, 2006) and post/within (i.e., 1st January, 2007 to 4th February, 2013) financial crisis variability.

The parameter of EGARCH (1,1), 'α' stands for the symmetric effect of the model. In Asia-Pacific region (table

8) α was largest during the financial crisis period but in Europe region (table 9) it was smallest. This is indicating that, during the financial crisis period volatility was much more sensitive in Asia-Pacific market compared to Europe. It proves Europe has more integrated market structure within the region, whereas Asia-Pacific markets do not have well integrated stock market system.

The leverage effect (γ) was positive for all Asia-Pacific markets (except India and Malaysia) during the financial crisis period and also larger than zero, which indicates that, the positive information are more destabilizing than the negative information. In case of India and Malaysia both have negative leverage effect, indicating positive shocks generate less volatility than the negative information or shocks for these two markets. In European region (table 9), all the leverage effect variables are positive during the crisis period and more than zero. For all the markets of this region, negative information propagates greater shock compared to the positive information.

The last parameter β represents the perseverance in conditional volatility irrespective of any incident in the market. For both the region in every scenario β is less than one and positive, implies that the volatility among these stock markets do not take longer to diminish following a catastrophic period.

Table 8. Parameter estimation of EGARCH (1,1) for regime switching (Asia-Pacific)

	India	Japan	China	Malaysia	Taiwan	South Korea	Singapore	Australia
1997-2013(Full Sample Period)								
ω	-7.028625***	-7.467567***	-5.839***	-0.374***	-6.940***	-3.221***	-1.324***	-8.126***
α	0.577485	-0.286307	0.671	1.890**	0.654	0.135	1.169	1.233**
γ	0.418527	0.889897	0.004	-1.629	0.492	0.886	-1.108	-0.676
β	0.242478	0.164072	0.403***	0.983***	0.231	0.075***	0.914***	0.228
1997-2006(Before Financial Crisis)								
ω	-7.341830***	-7.730703***	-2.645***	-0.475**	-6.838***	-5.151***	-0.533***	-8.056***
α	0.571981	0.289	0.998	0.270	0.231	0.434	1.164	2.194*
γ	0.371058	0.311	-0.369	0.076	0.584	0.654	-0.892	-1.6026
β	0.178330	0.100	0.769***	0.986***	0.215	0.454***	0.979***	0.2261
2007-2013(During/Post Financial Crisis)								
ω	-6.033160***	-3.649	-8.101***	-3.056***	-6.930***	-7.963***	-6.577***	-8.522***
α	1.350240	-0.628	0.291	3.734*	0.426	0.259	-0.325	0.1315
γ	-0.393247	0.898	0.420	-3.352	0.175	0.357	1.013	0.4077
β	0.411205*	0.620**	0.126	0.716***	0.283	0.183	0.371*	0.1733

Notes: *** 1%, ** 5%,* 10% level of significance.

Table 9. Parameter estimation of EGARCH (1,1) for regime switching (Europe)

	Austria	France	Germany	Greece	Italy	Netherlands	United Kingdom
1997-2013(Full Sample Period)							
ω	-7.987***	-6.947***	-6.966***	-1.309***	-5.859***	-6.457***	-7.992***
α	0.482	0.631	0.590	1.779	1.374	1.157	0.476
γ	0.259	0.186	0.372	-1.240	-0.557	-0.540	0.325
β	0.187	0.285*	0.279**	0.901***	0.465***	0.388***	0.183
1997-2006(Before Financial Crisis)							
ω	-5.975***	-7.415***	-5.799***	0.001	-5.680***	-7.923***	-7.609***
α	1.484	0.691	0.789	-0.306***	1.495	0.615	0.665
γ	-0.676	0.163	0.216	0.301***	-0.5360	-0.021	0.269
β	0.402*	0.216	0.426**	0.996***	0.507***	0.258**	0.214
2007-2013 (During/Post Financial Crisis)							
ω	-7.546***	-7.957**	-7.918***	-7.668***	-8.692***	-7.952***	-8.276***
α	0.218	0.202	0.222	-0.046	0.156	0.047	0.209
γ	0.379	0.342	0.372	0.602	0.365	0.264	0.359
β	0.188	0.152	0.176	0.142	0.126	0.176	0.172

Notes: *** 1%, ** 5%,* 10% level of significance.

4. Conclusion

The non-linearity of the logged market price is best suited to measure short term volatility transmission and the heteroscedastic nature of market price is a major motivation for portfolio balancing. The markets from both the regions show significant non-linearity to test for conditionality of the observations. The diagonal VECH parameterization primarily tests for own mean and own volatility spillover to test for the impact of historic volatility of host market or significance of "volatility spillover" effect. The third parameter tests for the cross volatility spillover indicating "contagion" of long term and short term shock among the markets. The finding is remarkable for both of the Asia/Pacific and European region. For the 8 major economies of the Asia/Pacific region own volatility spillover is more significant, and "volatility spillover" effect of the domestic market is more profound compared to "contagion" effect. The regime switch measures suggest, in compliance to "leverage effect" phenomenon, there is indication of turbulent markets post global financial crisis, but the shocks converge to mean and to do not persist, that is found with EGARCH parameterization. It explains that this region is integrated through more real linkage than financial linkage, and so is less vulnerable to a persistent global shock. In contrast to this, the European market exhibits more significant cross-volatility spillover and it is suggested that "financial contagion" is more significant the "volatility spillover" It must be noted financial contagion phenomenon can be explained with volatility transmission as well. The VECH matrix suggest, the 7 most significant sample markets from European region have sheer integration, and market anomalies spread instantaneously in the rest of the markets. The pure economic integration results in extreme financial linkage and leaves the markets to be highly vulnerable to persistent shocks similar to global financial crisis 2007. The regime switch phenomenon measures, shocks propagated within European markets may become acute but bears a similarity to the Asia/Pacific markets, that shocks will have mean reversion and will not persist for a considerably long period.

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