Volatility Spillovers in Emerging Markets During the Global Financial Crisis: Diagonal BEKK Approach

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Abstract

The fundamental aim of the paper is to analyze the presence and magnitude of the volatility transmissions in emerging markets, namely India, Hungary, Poland, Turkey and Brazil prior to, and during the latest financial turmoil. Using weekly returns of stock market indices from 2005 to 2011, the study applies Multivariate BEKK Methodology. The empirical results indicate that there exist significant volatility spillover effects for all five countries, though the spillovers are not homogeneous across the pairs. Results exhibit very large GARCH and relatively low ARCH effects. The study provides evidence of high level of financial integration in emerging markets. From an investor perspective, one important implication is that adding stocks from different emerging markets to a porfolio does not lead to risk reduction.

Keywords: Volatility Spillovers; Diagonal BEKK; Multivariate GARCH; Equity Markets

1. Introduction

The global financial landscape has changed. Weaker restrictions on capital mobility, technological advances and globalization of the world economy have given rise to highly integrated financial markets. With rapid transmission of news, changes in a particular market can impact returns and/or volatilities of other markets. Therefore, in order to design effective portfolio allocation and hedging decisions, it is crucial to analyze the co-movement dynamics between international stock markets.

The linkages between global equity markets have been studied extensively in recent years. There exists substantial evidence in the literature that large and developed markets like the U.S.

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impact smaller markets. Many studies have also found evidence of high level of financial integration between developed countries. However, the dynamics of integration are far less studied for the emerging world. Are developing-country equity markets highly integrated, i.e. do there exist return and volatility spillovers between them? Based on Markowitz and Sharpe-Lintners diversification principle, diversifying in emerging markets would only be beneficial if their stock markets do not move together[1]

The contribution of this paper is that it examines the presence and magnitude of return and volatility transmissions in the equity markets of India, Hungary, Poland, Turkey and Brazil prior to, and during the latest financial crisis. Using weekly returns of stock market indices from 2005 to 2011, a Five-Variate Diagonal BEKK Methodology is applied. These particular countries are chosen because they are fast-growing, and attract a rising number of investors. According to the data obtained from the World Federation of Exchanges (2011), Brazil has the highest global market cap (2.74%), followed by India (2.65%), Turkey (0.52%), Poland (0.35%), and Hungary (0.06%). As for their market performances, Polish and Turkish markets coped with the crisis relatively better than the rest due to their traditional banking system and limited exposure to the subprime mortgages.

By analyzing the linkages between equity markets of different sizes and in different regions, this study intends to provide a deeper understanding of the volatility transmission mechanism in the emerging world during the latest crisis. The rest of the paper is structured as follows: Section II reviews the previous literature and Section IV describes the methodology. Section V presents the data and empirical results and Section VI concludes.

2. Literature Review

There is a growing body of empirical literature that studies the transmission of volatility in international stock markets. Most researchers find that:

1. significant comovements are observed in world stock markets
2. correlations and volatility spillovers across stock markets rise in times of financial crisis

Such studies employ empirical strategies such as Grangers (1969) causality test, Sims (1980) vector autoregressive models, Engle and Grangers (1987) cointegration test and the ARCH/GARCH methodology. In recent years, multivariate GARCH models have been extensively used to analyze the comovements of stock markets and volatility spillovers.

The majority of the studies that employ multivariate GARCH models investigate the mean and volatility spillovers between developed and emerging markets. For example, Worthington and Higgs (2001) examine the transmission of equity returns and volatility among three developed markets (Hong Kong, Japan and Singapore) and six emerging markets (Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand). The results of the multivariate GARCH model generally indicate large and positive mean and volatility spillovers, and higher own volatility spillovers than cross volatility spillovers. Similarly, Li and Majerowska (2008) explores the linkages among the stock markets in Warsaw, Budapest, Frankfurt and the U.S. By using a four-variable asymmetric GARCH-BEKK model, they find evidence of return and volatility spillovers

[1] *The Comovements in International Stock Markets: New Evidence From Latin American Emerging Countries*, Arouri, Bellalah and Nguyen(2008).

from the developed to the emerging markets while he shows that the magnitude of volatility linkages is small. Also, Grosvenor and Greenidge (2010) analyze the co-movements of the regional stock markets of Jamaica, Trinidad, Barbaros and NYSE. With a multivariate GARCH model, they conclude that significant spillovers exist between each of the regional exchanges, as well as from the NYSE. Finally, Sariannidis, Konteos and Drimbetas (2010) analyze the volatility linkages between India, Singapore and Hong Kong from 1997 to 2005. Using a multivariate GARCH model, they prove that these markets show a strong GARCH effect and are highly integrated.

Some researchers, however, move their attention to analyzing the volatility linkages in equity markets during the latest crisis. Specifically, Frank and Hesse (2009) explore the financial co-movements between advanced economies and emerging markets during the subprime mortgage turmoil. They estimate a multivariate GARCH model and suggest that interlinkages between advanced economies and EM financial indicators have been highly correlated and seen sharp increases during the crisis period. In the same direction, Sun and Zhang (2009) investigate the spillovers of the United States to China and Hong Kong for the period 2005-2008. Using both univariate and multivariate GARCH models, they find volatility spillovers from United States to China and Hong Kong, with spillovers from U.S. to Hong Kong being more persistant than those to China. At the same time, the conditional correlation between China and Hong Kong outweighs their conditional correlations with United States because of the growing financial integration between these two countries.

In addition, there exist studies that focus exclusively on the co-movements of stock markets in emerging countries. Beirne, Caporale, Schulze-Ghattas and Spagnolo (2010) estimate trivariate GARCH(1,1)-in-mean models for 41 emerging markets in Asia, Europe, Latin America, and the Middle East. They find evidence of mean spillovers in emerging Asia and Latin America, and spillovers in variance in emerging Europe. They also detect cross-market GARCH-in-mean effects. Also, Bhar and Nikolova (2009) examine the level of integration of the BRIC equity markets (Brazil, Russia, India, China) with their respective regions and the world. Using a bivariate EGARCH model, they demonstrate that India shows the highest level of regional and global integration among the BRIC countries, followed by Brazil, Russia, and China. Lastly, Fedorova and Saleem (2010), using a bivariate GARCH-BEKK model, find evidence of mean and volatility linkages between the Eastern European emerging equity markets (Poland, Hungary, and Czech Republic) and Russia.

3. Econometric Methodology

Diagonal Bekk Model

First, the following mean equations are estimated for each market's own returns and the returns of other markets lagged one period:

$$R_T = \alpha + DR_{T-1} + \rho \times PCH(EMBI) + \sigma \times PCH(MSCI) \tag{1}$$

where PCH(EMBI) and PCH(MSCI) denote the percentage change in EMBI and MSCI indexes, respectively.

Next, the Diagonal BEKK methodology is employed in order to assess the volatility spillover effects between the five markets. Diagonal BEKK (Engle and Kroner, 1995) is a multivariate GARCH model that permits the explicit and dynamic parametrization of conditional covariances. It reduces the number of parameters estimated by restricting the parameter matrices to be diagonal and addresses the difficulty with VECH by ensuring that the conditional covariance matrix is always positive definite. The general Diagonal BEKK Equation is given as:

$$H_t = C'C + A'(\Xi_{t-1}\Xi'_{t-1})A + B'(H_{t-1})B \tag{2}$$

where H_t is an nxn conditional variance-covariance matrix, C is an upper triangular matrix of parameters, Ξ_{t-1} is an nx1 disturbance vector, and A and B are nxn diagonal parameter matrices. A trivariate Diagonal BEKK model can be described as follows.

Let be Ω an 3x3 matrix and equal to the $C'C$. The $C'C$ matrix equals:

$$\begin{aligned}
\Omega &= C'C \\
&= \begin{bmatrix} c_{11} & 0 & 0 \\ c_{12} & c_{22} & 0 \\ c_{13} & c_{23} & c_{33} \end{bmatrix} \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ 0 & c_{22} & c_{23} \\ 0 & 0 & c_{33} \end{bmatrix} \\
&= \begin{bmatrix} c_{11}^2 & c11c12 & c11c13 \\ c_{11}c12 & c12^2c22^2 & c12c13 + c22c23 \\ c_{11}c_{13} & c12c13 + c22c23 & c13^2c23^2c33 \end{bmatrix}
\end{aligned} \tag{3}$$

The H_t matrix can be represented as:

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix} \tag{4}$$

Finally, the equation becomes:

$$\begin{aligned}
\begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix} &= \begin{bmatrix} \Omega_{11,t} & \Omega_{12,t} & \Omega_{13,t} \\ \Omega_{21,t} & \Omega_{22,t} & \Omega_{23,t} \\ \Omega_{31,t} & \Omega_{32,t} & \Omega_{33,t} \end{bmatrix} \\
&+ \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix}' \left(\begin{bmatrix} u_{1,t-1} \\ u_{2,t-1} \\ u_{3,t-1} \end{bmatrix} \begin{bmatrix} u_{1,t-1} \\ u_{2,t-1} \\ u_{3,t-1} \end{bmatrix}' \right) \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \\
&+ \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} & h_{13,t-1} \\ h_{21,t-1} & h_{22,t-1} & h_{23,t-1} \\ h_{31,t-1} & h_{32,t-1} & h_{33,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}
\end{aligned} \tag{5}$$

Thus, each conditional variance and covariance equation are represented as:

$$
\begin{aligned}
h_{11,t} &= \Omega_{11} + a_{11}^2 u_{1,t-1}^2 + b_{11}^2 h_{11,t-1} && (6)\\
h_{12,t} &= \Omega_{12} + a_{11} a_{12} u_{1,t-1} u_{2,t-1} + b_{11} b_{22} h_{12,t-1} && (7)\\
h_{13,t} &= \Omega_{13} + a_{11} a_{33} u_{1,t-1} u_{3,t-1} + b_{11} b_{33} h_{13,t-1} && (8)\\
h_{22,t} &= \Omega_{22} + a_{22}^2 u_{2,t-1}^2 + b_{22}^2 h_{22,t-1} && (9)\\
h_{23,t} &= \Omega_{23} + a_{22} a_{33} u_{2,t-1} u_{3,t-1} + b_{22} b_{33} h_{23,t-1} && (10)\\
h_{33,t} &= \Omega_{33} + a_{33}^2 u_{3,t-1}^2 + b_{33}^2 h_{33,t-1} && (11)
\end{aligned}
$$

Under the assumption of conditional normality, the parameters of the multivariate GARCH models of any of the above specifications can be estimated by maximizing the log-likelihood function:

$$
l(\theta) = -\frac{TN}{2} - \frac{1}{2} \sum_{t=1}^{T} \left(\log |H_t| + \Xi_t H_{t-1}^{-1} \Xi_t \right) \tag{12}
$$

This study employs a 5-variate Diagonal BEKK Specification. The conditional mean and variance-covariances are estimated simultaneously with a system of five equations.

4. Data and Empirical Results

4.1. Data

The data employed in this study are the weekly closing prices of the IMKB 100 Stock Exchange of Turkey, the Warsaw Stock Exchange of Poland, the Budapest Stock Exchange of Hungary, the Bombay Stock Exchange of India, and the Bovespa Stock Exchange of Brazil. In addition, Morgan Stanley Capital International World Stock Index and JP Morgan Emerging Market Bond Index are used as exogenous variables. The data set covers the period from 01/01/2005 to 20/03/2011 and contains 326 observations for each series. The data are obtained from *Thompson Reuters Data Provider*. The weekly returns are computed as the difference of the natural logarithm of two consecutive weekly prices, i.e. $R_t = \left(ln(\frac{P_t}{P_{t-1}}) \right)$.

Table 1: Variables

Index	Definition
XU100P	Istanbul Stock Exchange IMKB100 Price Index Series
WIGP	Warsaw Stock Exchange Price Index Series
BUXP	Budapest Stock Exchange Price Index Series
BVSPP	Brazil Stock Exchange Bovespa Price Index Series
BSE100P	Bombay Stock Exchange Price Index Series
MSCI	Morgan Stanley Capital International World Stock Index
EMBI	JP Morgan Emerging Market Bond Index

Table 2: Weekly Stock Market Returns from 2005 to 2011

	XU100P	WIGP	BUXP	BVSPP	BSE100P	MSCI	EMBI
Mean	0.0030	0.0019	0.0013	0.0029	0.0031	0.0037	-0.0004
Median	0.0072	0.0046	0.0031	0.0071	0.0084	0.0056	-0.0069
Maximum	0.1576	0.1158	0.1516	0.1684	0.1522	0.0663	0.3622
Minimum	-0.1927	-0.171	-0.2689	-0.2233	-0.1851	-0.1139	-0.2646
Std.Dev.	0.0417	0.0324	0.0411	0.0402	0.0384	0.0236	0.0591
Skewness	-0.4477	-0.7021	-1.0137	-0.6381	-0.6049	-1.2394	1.1204
Kurtosis	5.2328	5.9508	9.4039	7.5656	5.8292	7.1855	10.4682
Jarque-Bera	78.6082	145.0559	612.8956	305.2549	128.6030	321.4199	825.7968
J.B.Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	0.963400	0.6054	0.4079	0.9580	1.0005	1.2222	-0.1182
Sum Sq.Dev.	0.5643	0.3407	0.5491	0.5242	0.4796	0.1804	1.1340
Observations	326	326	326	326	326	326	326

4.2. Descriptive Statistics

Descriptive statistics for each market return between 01/01/2005 and 20/03/2011 are reported in Table 2. Distributional properties of weekly returns seem to be non-normal. Jarque-Bera estimates normality of distribution, P-value of Jarque-Bera test is significant at 1% in all cases, we reject the null hypothesis of normality. All stock markets are negatively skewed and kurtosis exceeds 4, demonstrating a leptokurtic distribution. Plots of weekly stock market prices and returns for each country are illustrated below.All return series display volatility clustering and leverage effects, making ARCH models applicable.

Weekly Stock Market Prices: 2005-2011

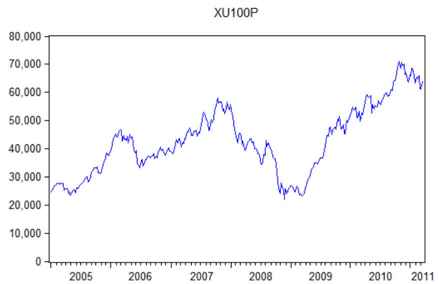

Figure 1: Turkey

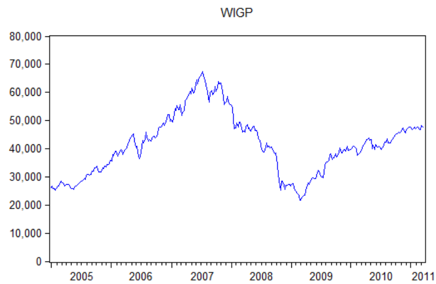

Figure 2: Poland

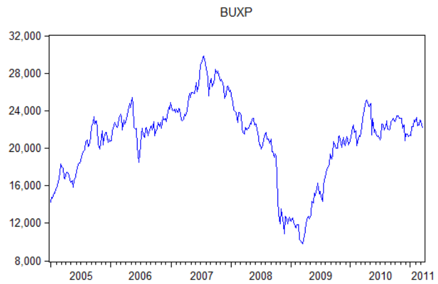

Figure 3: Hungary

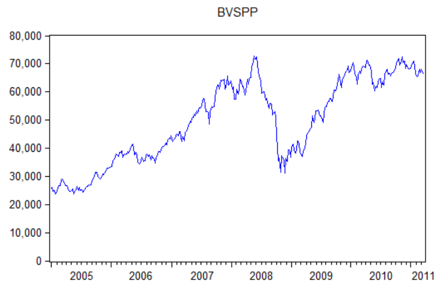

Figure 4: Brazil

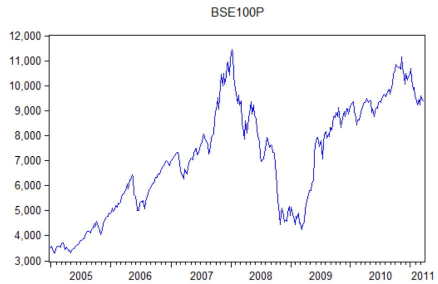

Figure 5: India

Weekly Stock Market Returns: 2005-2011

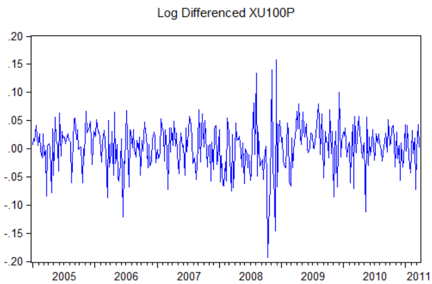

Figure 6: Turkey

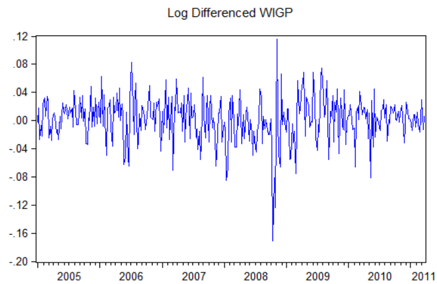

Figure 7: Poland

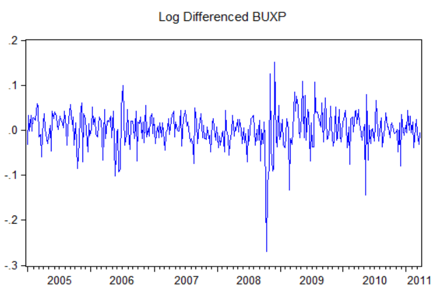

Figure 8: Hungary

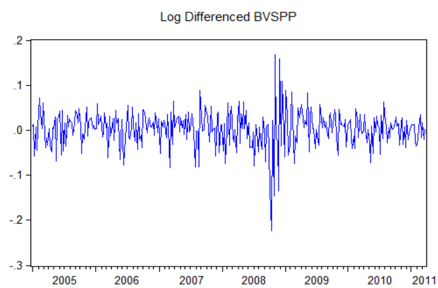

Figure 9: Brazil

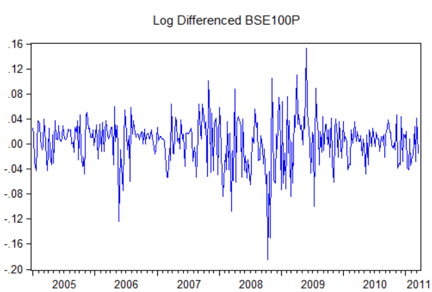

Figure 10: India

4.3. The Mean Return Spillovers

Results of conditional mean return equations are reported in Table 3. Diagonal parameters d_{11}, d_{33} and d_{44}, are statistically significant, suggesting that the returns of Turkey, Hungary and Brazil are dependent on their first lags. These own mean spillovers are high and negative, indicating a downward drift in these markets. Diagonal parameters d_{22} and d_{55} are insignificant in case of Poland and India, showing that their returns do not depend on their own previous returns.

Table 3: Estimated Coefficients for Conditional Mean Return Equations

	Coefficient	St. Error	Coefficient	St. Error	Coefficient	St. Error
	TURKEY=1		POLAND=2		HUNGARY(i=3)	
α	0.002187	0.002034	0.001055	0.001564	0.000295	0.002039
d_{i1}	-0.163461**	0.082626	0.064806	0.093038	0.063197	0.079361
d_{i2}	-0.023624	0.048670	0.006868	0.072740	0.062937	0.065150
d_{i3}	0.062975	0.064695	0.095646	0.097867	-0.141629*	0.077275
d_{i4}	-0.020588	0.055875	0.101086	0.079266	-0.000234	0.064327
d_{i5}	0.044716	0.064866	0.033614	0.086434	0.044716	0.490600
EMBI	-0.341556***	0.036355	-0.250988***	0.031914	-0.346673***	0.029758
MSCI	0.262875**	0.111551	0.299431***	0.082526	0.272067***	0.100737
	BRAZIL(i=4)		INDIA=5			
α	0.001741	0.001659	0.001757	0.001933		
d_{i1}	-0.001956	0.067991	0.121950*	0.066514		
d_{i2}	0.004706	0.059416	0.053407	0.044304		
d_{i3}	0.127614*	0.071137	-0.021193	0.065248		
d_{i4}	-0.171623***	0.061121	0.056783	0.051411		
d_{i5}	0.061906	0.063261	-0.060930	0.063663		
EMBI	-0.349677***	0.026032	-0.249651***	0.031927		
MSCI	0.439765***	0.087702	0.266691***	0.097258		

[1] Notes: *significant at level of 10%,**significant at level of 5%, *** significant at level of 1%.

Cross-mean spillovers are insignificant in all models, except for d_{51}, India to Turkey(0.1219) and d_{43}, Brazil to Hungary(0.1276). The results mean that highest cap markets, India and Brazil, have positive spillover effects on the smaller markets of Turkey and Hungary, respectively. Next, Wald Test is performed for each country, in order to test the null hypothesis that mean spillovers from other markets equal zero. The null cannot be rejected for all markets, except for Hungary. Hence, only Hungarian returns are significantly affected by lagged returns of other emerging markets. Insignificant cross mean spill-overs show that Turkey, Poland, India and Brazil markets are not influenced by the local events in other markets.

In contrast, there exist returns spillovers from EMBI and MSCI to all five exchanges. The coefficient of EMBI—which represents the performance of government bonds in emerging countries is negative and highly significant for all countries. Hence bond markets have a highly negative effect on emerging market stock returns. One possible explanation is that investors demand higher rates of interest in times of volatility; therefore, high bond returns follow low stock prices.

On the other hand, the coefficient of MSCI—a common benchmark for global stock funds—is positive and significant. Emerging market stock returns seem to be positively correlated with global markets as information about global economic conditions get transmitted into the pricing process of regional stocks. Mean effects originating from global stock and bond markets are considerably larger than those originating from lagged mean returns. These results suggest that emerging markets are highly susceptible to global markets. Moreover, they derive their correlation from global, rather than domestic events.

4.4. The Volatility Spillovers

Conditional variance-covariance equations effectively capture the volatility and cross volatility among the five stock markets because most coefficients are statistically significant(Table 4). Specifically, conditional variances-covariances implied by the Diagonal BEKK Specification are presented below.

$$h_{11,t} = 0.000204 + 0.026012\epsilon^2_{1,t-1} + 0.781443h_{11,t-1} \tag{13}$$
$$h_{12,t} = 4.430574e-05 - 0.00991\epsilon_{1,t-1}\epsilon_{2,t-1} + 0.872133h_{12,t-1} \tag{14}$$
$$h_{13,t} = 7.397949e-05 + 0.022939\epsilon_{1,t-1}\epsilon_{3,t-1} + 0.822285h_{13,t-1} \tag{15}$$
$$h_{14,t} = 4.154376e-05 + 0.040308\epsilon_{1,t-1}\epsilon_{4,t-1} + 0.837378h_{14,t-1} \tag{16}$$
$$h_{15,t} = 3.927877e-05 + 0.041227\epsilon_{1,t-1}\epsilon_{5,t-1} + 0.839813h_{15,t-1} \tag{17}$$
$$h_{22,t} = 1.534778e-05 + 0.003775\epsilon^2_{2,t-1} + 0.973348h_{22,t-1} \tag{18}$$
$$h_{23,t} = 3.972925e-05 - 0.008739\epsilon_{2,t-1}\epsilon_{3,t-1} + 0.917715h_{23,t-1} \tag{19}$$
$$h_{24,t} = 1.854278e-05 - 0.015356\epsilon_{2,t-1}\epsilon_{4,t-1} + 0.934559h_{24,t-1} \tag{20}$$
$$h_{25,t} = 1.596628e-05 - 0.015706\epsilon_{2,t-1}\epsilon_{5,t-1} + 0.937277h_{25,t-1} \tag{21}$$
$$h_{33,t} = 0.000114 + 0.020229\epsilon^2_{3,t-1} + 0.865261h_{33,t-1} \tag{22}$$
$$h_{34,t} = 2.950726e-05 + 0.035546\epsilon_{3,t-1}\epsilon_{4,t-1} + 0.881142h_{34,t-1} \tag{23}$$
$$h_{35,t} = 2.415015e-05 + 0.036357\epsilon_{3,t-1}\epsilon_{5,t-1} + 0.883704h_{35,t-1} \tag{24}$$
$$h_{44,t} = 3.221746e-05 + 0.06246\epsilon^2_{4,t-1} + 0.897315h_{44,t-1} \tag{25}$$
$$h_{45,t} = 1.356436e-05 + 0.063884\epsilon_{4,t-1}\epsilon_{5,t-1} + 0.899925h_{45,t-1} \tag{26}$$
$$h_{55,t} = 3.490055e-05 + 0.065341\epsilon^2_{5,t-1} + 0.902542h_{55,t-1} \tag{27}$$

From these empirical results we conclude a strong evidence of GARCH effect and the presence of a weaker ARCH effect. Equations show a statistically significant covariation in shocks, which depends more on its lags than on past errors. Consequently, market shocks are influenced by past information which is common to the respective markets.

Own-volatility spillovers(ARCH effects) are positive and significant for all five exchanges. The spillover effect is higher for India(0.0653) and Brazil(0.0624) than for Turkey(0.026), Hungary(0.02), and Poland(0.02). These coefficients show the volatility persistence for each market in terms of its own past errors. As for cross-volatility effects, past innovations in India have greatest influence in future volatility of other developing market returns. In the case of India, Brazil has the greatest influence on its future volatility. The cross-volatility spillovers are higher than own-volatility spillovers in all markets except for India.

Therefore, past volatility shocks in other emerging markets have greater effect on future volatility than domestic volatility shocks in case of Turkey, Poland, Hungary and Brazil. These results suggest that India is the least vulnerable market to outside shocks.

Table 4: Estimated Coefficients for Conditional Variance-Covariance Equations

	Coefficient	St. Error
C(1,1)	0.000204	0.000149
C(1,2)	4.43E-05	2.80E-05
C(1,3)	7.40E-05*	4.19E-05
C(1,4)	4.15E-05	2.60E-05
C(1,5)	3.93E-05	2.59E-05
C(2,2)	1.53E-05***	5.58E-06
C(2,3)	3.97E-05*	2.26E-05
C(2,4)	1.85E-05**	7.68E-06
C(2,5)	1.60E-05***	5.95E-06
C(3,3)	0.000114	8.07E-05
C(3,4)	2.95E-05*	1.56E-05
C(3,5)	2.42E-05*	1.26E-05
C(4,4)	3.22E-05**	2.15E-05
C(4,5)	1.36E-05**	6.70E-06
C(5,5)	3.49E-05*	1.95E-05
A(1,1)	0.161282**	0.072931
A(2,2)	-0,061443	0.032368
A(3,3)	0.142230***	0.054074
A(4,4)	0.249920***	0.064238
A(5,5)	0.255619***	0.051757
B(1,1)	0.883993***	0.083833
B(2,2)	0.986584***	0.005333
B(3,3)	0.930194***	0.048982
B(4,4)	0.947267***	0.027734
B(5,5)	0.950022***	0.019674

[1] Notes: *significant at level of 10%,**significant at level of 5%, *** significant at level of 1%.

The lagged own-volatility persistence(GARCH effects) is Poland(0.9733), India(0.9025), Brazil(0.8973), Hungary(0.8653) and Turkey(0.7814). These results suggest that Poland derives more of its volatility persistence from within the domestic market, while Turkey derives more of its volatility persistence from outside the domestic market. Moreover, the own volatility spillover effects for five exchanges do not remain within a tight range. This further implies that each emerging market faces a different risk-return profile and different levels of vulnerability to outside conditions.

For Turkey the lagged cross-volatility persistence ranges from 0.8721(Poland) to 0.8223 (Hungary), and in Poland it goes from 0.9373 (India) to 0.8721(Turkey). Conversely, in Hungary the cross-volatility persistence varies between 0.9177(Poland) and 0.8223(Turkey), while in Brazil it goes from 0.9346(Poland) to 0.8374(Turkey), and in India from 0.9373(Poland) to 0.8398(Turkey). Hence, in terms of cross-volatility persistence, the least influential market in the study is Turkey while the most influential would appear to be Poland. On the other hand, past volatility shocks in India have greatest effect on the future volatility of Poland.

It is an important finding here that although cross-volatility persistence is heterogeneous for five exchanges, least and most influential markets remain the same. Moreover, the order of influence does not depend on the size nor the market cap. Influence of lagged covariance on future covariance is found positive for all pairs and coefficients range from 0.8223 (Turkey-Hungary) to 0.9373(India-Poland). The analysis implies that the magnitude of cross volatility persistence is not directly linked to geography or economic relations between the countries. It can be due to the level of integration of the market to rest of the world.

The plots for the conditional variances-covariances estimated by the Diagonal BEKK Model are illustrated below. They suggest that the comovements of the stock markets display an extremely volatile trend for the study period. Moreover, the conditional correlations show sharp increases at some point during 2008-2009 for each pair of countries. This provides evidence that examined emerging markets are highly integrated and that volatility spillovers rise during global crisis.

Finally, the Ljung-Box Q statistics show no evidence of autocorrelation in the standardized residuals (Table 5). It can be concluded that the conditional mean return equations are correctly specified with the diagonal BEKK GARCH model.

Table 5: Portmanteau Test using Standard Residuals

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	5.222543	1.0000	5.239175	1.0000	25
2	39.85245	0.8473	40.09036	0.8407	50
3	63.66125	0.8217	64.12809	0.8104	75
4	93.62364	0.6603	94.47584	0.6371	100
5	121.7574	0.5654	123.0634	0.5322	125
6	166.3136	0.1716	168.4847	0.1436	150
7	194.5329	0.1485	197.3454	0.1185	175
8	227.5072	0.0885	231.1790	0.0646	200
9	244.2449	0.1804	248.4090	0.1360	225
10	275.6288	0.1274	280.8218	0.0877	250
11	297.3430	0.1695	303.3218	0.1157	275
12	326.1059	0.1438	333.2237	0.0907	300

[1] Null hypothesis: No residual autocorrelation up to lag h
[2] Orthogonalization: Cholesky(Lutkepohl)

Conditional Variances-Covariances Estimated by Diagonal BEKK

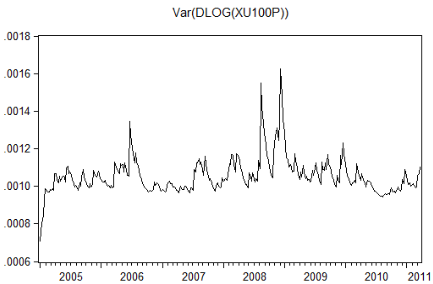

Figure 11: VAR(Turkey)

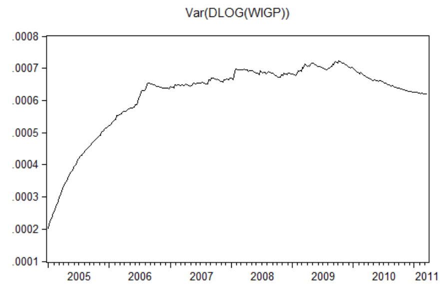

Figure 12: VAR(Poland)

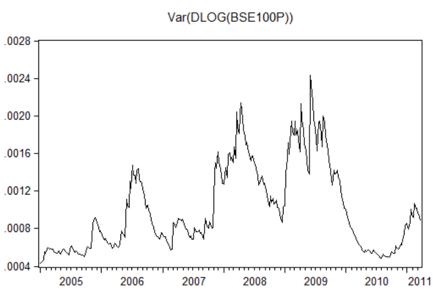

Figure 13: VAR(India)

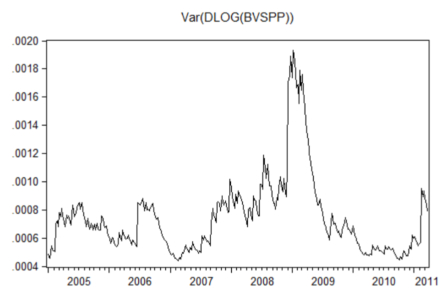

Figure 14: VAR(Brazil)

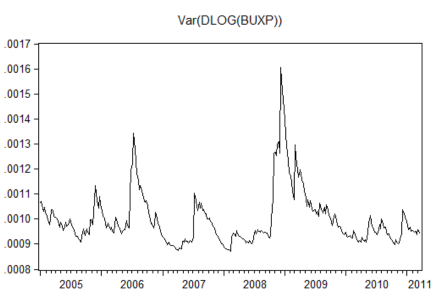

Figure 15: VAR(Hungary)

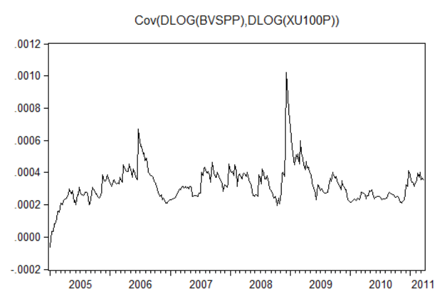

Figure 16: COV(Turkey,Brazil)

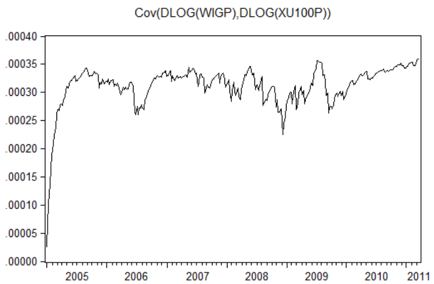

Figure 17: COV(Turkey,Poland)

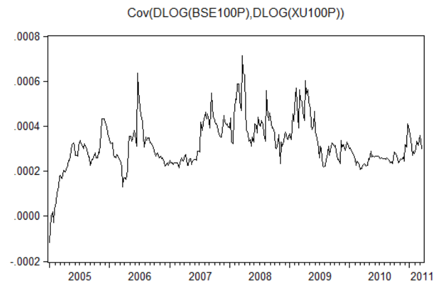

Figure 18: COV(Turkey,India)

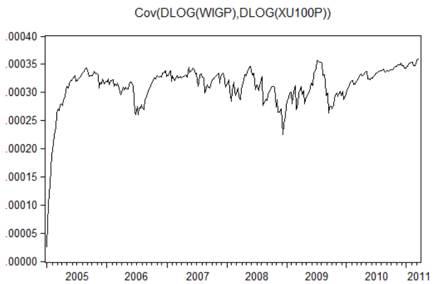

Figure 19: COV(Turkey,Poland)

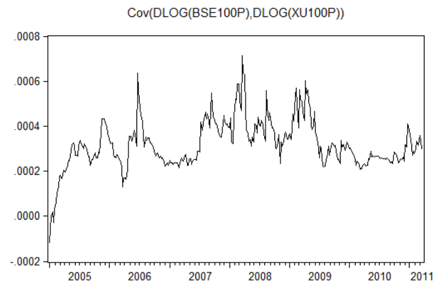

Figure 20: COV(Turkey,India)

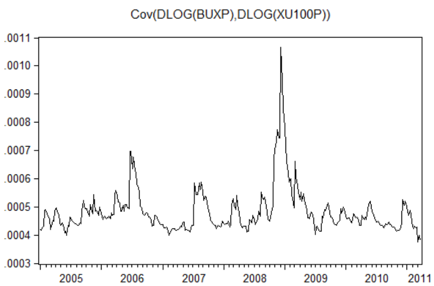

Figure 21: COV(Turkey,Hungary)

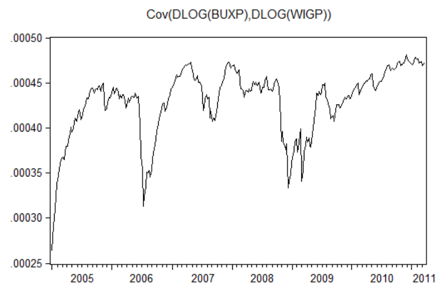

Figure 22: COV(Poland,Hungary)

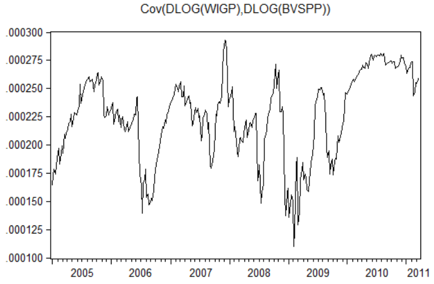

Figure 23: COV(Poland,Brazil)

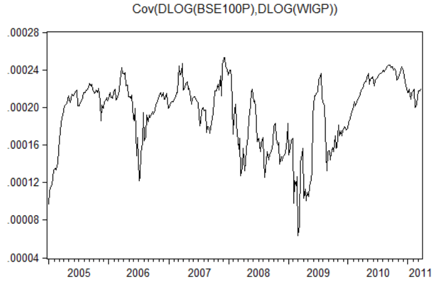

Figure 24: COV(Poland,India)

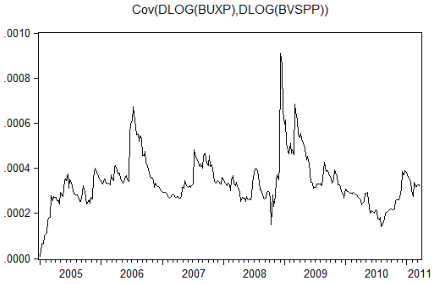

Figure 25: COV(Hungary,Brazil)

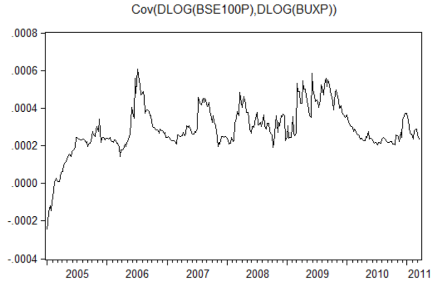

Figure 26: COV(Hungary,India)

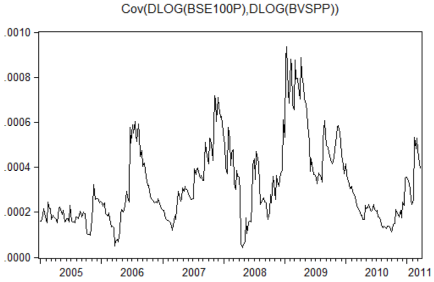

Figure 27: COV(Brazil,India)

5. Conclusion

Mean equations show that emerging markets are strongly linked to global markets during the study period. For all systems, coefficients for EMBI and MSCI are high and significant. Conversely, cross-mean spillovers are insignificant for most equations. Moreover, own mean spillover coefficients are negative and significant only for Turkey, Hungary and Brazil, suggesting that their stock returns have been highly volatile, alternating, and negatively linked to one period lagged returns. Overall, mean equation analysis indicates that emerging countries derive their volatility from global, rather than their domestic markets.

In conditional variance-covariance equations, there exist significant and strong volatility spillover effects for all five emerging markets. Magnitude of the estimates is not homogeneous across countries but remains within a relatively tight range. Influence of lagged covariance on future covariance is found to be positive in all estimations and is extremely high with values often greater than 85%. Hence the Diagonal BEKK Model exhibits very large GARCH and relatively low ARCH effects. Comovement across emerging markets does not appear to be directly linked to geography or economic relations between the countries due to financial globalization and integration.

One important implication of this study is that adding stocks only from these five emerging markets will not diversify away portfolio risk. Investors must diversify their portfolios employing not only emerging, but also developed market stocks. Correlations and volatility spillover effects between emerging and developed stock markets must be studied and taken into account.

The last but not the least, the high level of financial integration may weaken emerging markets against external shocks. Decision makers in the emerging world must now design policies not only looking at domestic estimates, but also by considering the fact that emerging markets are now highly linked both among each other and with the global markets. Hence, global financial landscape has changed, and the emerging world is no exception.

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