Transmission Of The Subprime Crisis: Evidence From Industrial And Financial Sectors Of BRIC Countries

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ABSTRACT

Although, there is an apparent consensus about the contagion effects of the current US subprime crisis. However, the transmission and repercussions of US subprime crisis, as well as the nature of the transformation suffered by different economic sectors between the US and other markets are such empirical questions that have not been dealt with comprehensively, yet. In this paper, by utilizing the multivariate GARCH analysis of Engle and Kroner (1995) for which a BEKK representation is adopted, we examine the transmission of the US subprime crisis across BRIC financial markets. Moreover, to identify the extent of contagion, we also inspect the diffusion of US subprime crisis to BRIC equity market's financial and industrial sectors. We found interesting evidence of volatility spillovers from US financial sector to all the BRIC market's financial sectors both in the full sample and crisis period. Similarly, except Chinese industrial sector, we observe contagion effects from US to Brazilian, Russian and Indian equity market's industrial sectors. Our results exhibit direct linkage for both returns and volatility between the US equity market and the BRIC markets. Equity markets of Russia and India, however, were found hardly hit during the crisis period among the BRIC countries. Finally, we found no support for the decoupling view while investigating the fastest growing emerging markets, the BRIC countries.

Keywords: Subprime Crisis Transmission; Contagion; BRIC Equity Markets; Financial Sector; Industrial Sector

INTRODUCTION

T he ongoing subprime crisis originated from the burst of real estate sector bubble in the United States appeared to be the most disastrous one for the financial houses, industrial growth and stock markets around the globe. In fact, this crisis has uncovered the insidious flaws in financial industry regulations and questioned the realism of the global financial system.

Although, there is an apparent consensus about the contagion effects of the current US subprime crisis. However, the transmission and repercussions of US subprime crisis, as well as the nature of the transformation suffered by different economic sectors between the US and other markets are such empirical questions that have not been dealt with comprehensively, yet. Only limited literature is available till today, for instance, by utilizing structural vector autoregressive model Angkinand et al (2009) examines the spillover effects from the U.S. financial crisis to 17 advanced economies. Their results indicate that the extent of interdependence was at peak after the emergence of the U.S. subprime crisis. Similarly, Lee (2012) investigates the correlations between the US returns and 20 international stock returns consisting both developed and emerging markets. Furthermore, Yılmaz (2010) through variance decomposition analysis of the VAR model inspect the extent of contagion and interdependence across the East Asian equity markets during the current global financial crisis and found evidence of direct linkage between the equity markets with regards to returns and volatility. Furthermore, by applying dynamic correlations Fidrmuc and Korhonen (2010) investigate the transmission of US subprime crisis to China and India and conclude that the current financial crisis has had a significant effect on their economic developments and business cycles.

More recently, Cheung et al (2010) analyze the market interdependence and spillover effect of credit risk during 2007–2009 global financial crisis to UK, Hong Kong, Japan, Australia, Russia and China and found evidence of contagion. Dimitriou and Simos (2013) found empirical evidence of contagion of the USA subprime financial crisis to EMU, China and Japan equity markets.

Studies investigating the affects of US subprime crisis on BRIC countries are even scarce, exceptions includes, for instance, Bhar and Nikolova (2009) who investigate return and volatility spillovers and dynamic correlation in the BRIC equity markets. Bianconi et al (2013) study the co movement of stock and bond markets BRIC during the U.S. financial crisis. Similarly, Aloui et al (2011) study the co movement of equity markets between BRIC and US market; their empirical findings confirm strong support of time-varying dependence between each of the BRIC markets and the US market.

This paper examines the transmission of the ongoing US subprime crisis to Brazil, Russia, India and China, representatives of the fastest growing emerging economies of the world, and investigates if, and to what extent, these emerging markets have been affected by the crisis, by analyzing their stock markets and industrial and financial sectors of their equity markets. These particular markets are of special interest since BRIC economies have been perhaps the key performers in the world economy in the past two decades. During their gradual process of development developed world has certainly recognized their economic importance and even BRIC markets have begun to influence economic developments in other emerging countries by setting standards to grow. This growth has been dominated particularly by the rising Chinese economy, due to its export driven policies and a huge foreign investment from developed countries. Within no time, China has turn out to be an important player for the global economy. At the same time, India, Russia and Brazil are in chase of Chinese economic development. In short, growth in BRIC economies has changed the direction of economic performance across the globe. Between 1988 and 2008, the share of BRIC economies GDP in the world economy increased from 7% to 15 % (valued at market exchange rates). Among the countries Chinese GDP in the world economy increased from 1.7% to 7.1%, Brazil and Russia contribute 2.7 % each, while Brazil's share of global output was only 2%. Enormous increased in the stock market indices of BRIC countries during the last decade, for example, Brazil's Bovespa Index rose 342%, China's Shanghai Composite Index rose 75%, India's Sensex Index rose 250% and Russia's Micex Index rose 638%, is another evidence of their potential role in the future of global economy.

Another objective of this paper is to examine the so called "decoupling" theory phenomenon, See, for instance, Ricardo et al (2010) and Eichengreen and Park (2008). At the early phase of US subprime crisis, many believed that BRIC economies were isolated from the global economic chaos. The argument behind this believe was the so called decoupling theory, which assumes that the U.S. economy is no longer the driver of world economic growth but the fastest growing economies, such as emerging Asia and Europe. However many recent studies, such as, Frank and Hesse (2009), Dooley and Hutchison (2009) as well as Pula and Peltonen (2009) found no support for the decoupling view while investigation of emerging markets of Asia. Since BRIC markets are known as the economic engine of the world today it would be interesting to see whether decoupling theory is true for BRIC countries.

On the whole, to investigating the interdependence among US equity market and BRIC equity markets as well as to explore the contagious affects of US subprime crisis on BRIC equity markets, Among others, Following Saleem (2008), Shamiri and Isa (2009) and Caporale et al (2006) we purpose Engle and Kroner (1995) multivariate GARCH analysis for which a BEKK representation is adopted. Additionally, in view of the fact that BRIC markets have strong links with the global economy through trade and financial channels; we examine the transmission of US subprime crisis to BRIC equity market's financial and industrial sectors to identify the extent of contagion. Four pair-wise models for global indices are estimated for USA with Brazil, Russia, India and China and eight bi-variate models are estimated for sectoral indices, representing the financial and the industrial sectors in each market analysed on the basis of daily total return indices. We divide our analysis in three parts, pre crisis (Jan. 2000 – Jul 2007), crisis period 1 (Aug 2007 – Aug. 2008), start of the world wide credit crunch in August 2007 but before the Lehman Brothers' bankruptcy in September 2008, crisis period 2 (Sep. 2008 – Dec. 2009) Lehman Brothers' bankruptcy in September 2008 till the end of 2009. Our results exhibit direct linkage for both returns and volatility between the US equity market and the BRIC markets. For instance, in case of return spillovers, both crisis periods exhibit highly significant return spillovers from US market to all the BRIC countries markets and their sectors.

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Results for the pre crisis period shows that India and Russian equity returns as well as their financial and industrial sector returns were highly effected by the movements in US equity market and its financial and industrial sectors. Likewise, results for volatility establish clear evidence of contagion, at least in equity and industrial sector, however, only Russian financial sector found severely hit after the Lehman Brothers' bankruptcy. In addition, following prior research, to examine the long-term relationship among the markets we utilize Johansen cointegration test and to examine the causality affects between two markets we apply Granger Causality Test. Both the conventional methods also support our results obtained by using multivariate GARCH- BEKK representation.

It is our contention that a clearer understanding of the US subprime crisis from the perspective of international interdependence during crisis periods hold value for persons such as international investors, multinational corporations and portfolio managers seeking to minimize or manage their exposures to financial risk. International transmission of stock market volatility also impacts corporate capital budgeting decisions, investor consumption decisions and other business cycle variables.

The plan of the paper is as follows. The next section describes the bivariate GARCH models used to study the volatility spillovers among stock markets and sectoral indices and to identify the extent of US subprime contagion. Section 3 presents the data in this study. Section 4 shows the empirical results. Section 5 concludes.

MODEL SPECIFICATION

We start our empirical specification with a bivariate VAR-GARCH (1, 1) model that accommodates each market's returns and the returns of other markets lagged one period.[1]

$$\begin{bmatrix} r_{1,t} \\ r_{2,t} \end{bmatrix} = \begin{bmatrix} a_{1,0} \\ a_{2,0} \end{bmatrix} + \begin{bmatrix} \beta_{1,1} & \beta_{1,2} \\ \beta_{2,1} & \beta_{2,2} \end{bmatrix} \begin{bmatrix} r_{1,t-1} \\ r_{2,t-1} \end{bmatrix} + \begin{bmatrix} \mu_{1,t} \\ \mu_{2,t} \end{bmatrix} \tag{1}$$

$$u_t | \Omega_{t-1} \sim N(0, H_t), \tag{2}$$

where r_t is a n×1 vector of daily returns at time t for each market. The n×1 vector of random errors μ_t represents the innovation for each market at time t with its corresponding n×n conditional variance-covariance matrix H_t. The market information available at time t-1 is represented by the information set Ω_{t-1}. The n×1 vector, α, represents the constant. The own market mean spillovers and cross-market mean spillovers are measured by the estimates of matrix β elements, the parameters of the vector autoregressive term. This multivariate structure thus facilitates the measurement of the effects of innovations in the mean stock returns of one series on its own lagged returns and those of the lagged returns of other markets.

Given the above expression, and following Engle and Kroner (1995), the conditional covariance matrix can be stated as:

$$H_t = C_0' C_0 + A_{11}' \varepsilon_{t-1} \varepsilon_{t-1}' A_{11} + G_{11}' H_{t-1} G_{11}, \tag{3}$$

where the parameter matrices for the variance equation are defined as C_0, which is restricted to be lower triangular and two unrestricted matrices A_{11} and G_{11} (Gema). Thus, the second moment can be represented by:

$$H_t = C_0' C_0 + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}, \varepsilon_{2,t-1} \\ \varepsilon_{1,t-1}, \varepsilon_{2,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \tag{4}$$

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[1] This model is based on the bivariate GARCH (1, 1)-BEKK representation proposed by Engle and Kroner (1995).

Following Engle and Kroner (1995) the above system can be estimated by the maximum likelihood estimation which can be optimised by using the Berndt, Hall, Hall and Hausman (BHHH) algorithm. From equations (4) we obtain the conditional log likelihood function L(θ) for a sample of T observations:

$$L(\theta) = \sum_{t=1}^{T} l_t(\theta),$$

(5)

$$l_t(\theta) = -\log 2\pi - 1/2 \log |H_t(\theta)| - 1/2 \varepsilon_t'(\theta) H_t^{-1}(\theta) \varepsilon_t(\theta)$$

(6)

where θ denotes the vector of all the unknown parameters. Numerical maximisation of equation (4) yields the maximum likelihood estimates with asymptotic standard errors.

Finally, to test the null hypothesis that the model is correctly specified, or equivalently, that the noise terms, μ_t, are random, the Ljung-Box Q-statistic is used. It is assumed to be asymptotically distributed as χ2 with (p − k) degrees of freedom, where k is the number of explanatory variables. Moreover, as robustness checks we also examine the long-term relationship among the markets by utilizing Johansen cointegration test. Finally to examine the causality affects between two markets we apply Granger Causality Test.

DATA AND DISCRIPTIVE STATISTICS

The data comprise daily total return indices calculated by DataStream for the US equity market, its Industrial and Financial sector, and Brazilian, Russian, Indian and Chinese equity markets and their Industrial and Financial sectors. The dataset starts from January 2000 and ends at December 2009, yielding 2609 observations in total for each series. While analysing the contagion effect of US subprime crisis 2007, two crisis periods were defined, first from August 2007 (burst of the mortgage bubble, assumed to have occurred) to August 2008, before the Lehman collapse and second from September 2008 to December 2009. Figure 1 shows the development of equity markets of BRIC countries and US market and Figure 2 and 3 presents the development of financial and industrial sectors of BRIC countries and US market. All the data are retrieved from DataStream, and daily returns are constructed as the first difference of logarithmic prices multiplied by 100. Stationarity in the time series is checked by applying the Augmented Dickey Fuller (ADF) test. To check the null hypothesis of normal distribution we calculate Jarque-Bera test statistic. Finally, to investigate the null that autocorrelation coefficients up to 26 lags are zero, we compute Ljung and Box (1978) test statistic, together with the ARCH LM-statistic (five lags) on each returns series. The results (not presented, available on request) allow us to reject the null hypothesis that returns have unit root in favor of alternate hypothesis of stationarity (even at 1% MacKinnon critical value), reject the normality and allow us to use GARCH specification through LB statistics and ARCH LM-statistic.
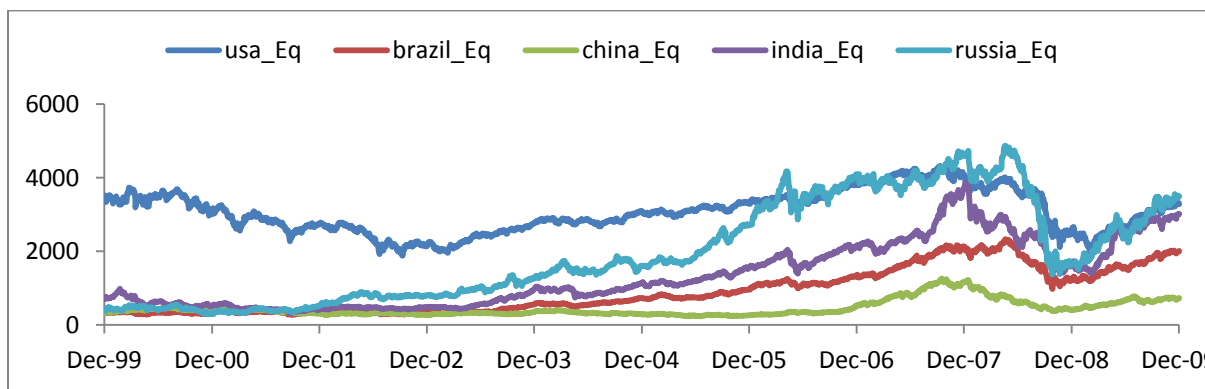

Figure 1: Equity Market Development

EMPIRICAL RESULTS

Our empirical results answer the theoretical questions formulated in the previous sections. First, to examine the return and volatility transmission of US stock market four pair-wise models are estimated utilizing bivariate GARCH frame work, for which a BEKK representation is adopted (see, e.g., Engle and Kroner, 1995). Moreover, in view of the fact that BRIC markets have strong links with the global economy through trade and financial channels; we examine the transmission of US subprime crisis to BRIC equity market's financial and industrial sectors to identify the extent of contagion, eight bivariate models are estimated for sectoral indices, representing the financial and the industrial sectors in each market analysed on the basis of daily total return indices calculated by DataStream from January 2000 to December 2009.

Table 1 Volatility Spillovers between US and Brazilian Equity Markets and Their Industrial and Financial Sectors Estimated from a Bivariate VAR - GARCH(1, 1)-BEKK Model of Daily Return Indices

The diagonal and off diagonal elements in matrix Beta measures own and cross-market return effect and diagonal and off diagonal elements in matrix Gama measures own and cross-market GARCH effects. EQ represents equity markets, IND and FIN stands for industrial and financial sector of the equity markets respectively. i and j represent USA and Brazil. Sample period is from January 2000 to August 2007 consisting of 1071 daily observations for pre crisis period. Crisis period is chosen between August 2007 and August 2008 and September 2008 till December 2009, representing before and after the collapse of Lehman Brothers.

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Pre Crisis					
	Coeff	Signif		Coeff	Signif
Beta_EQi,j	0.040	0.018	Gema_EQi,j	0.016	0.127
Beta_EQj,i	0.004	0.895	Gema_EQj,i	0.003	0.626
Beta_INDi,j	-0.018	0.209	Gema_INDi,j	-0.006	0.514
Beta_INDj,i	0.057	0.014	Gema_INDj,i	-0.019	0.152
Beta_FINi,j	0.008	0.562	Gema_FINi,j	0.017	0.110
Beta_FINj,i	0.013	0.611	Gema_FINj,i	0.001	0.855
Panel B: VAR - GARCH(1, 1)-BEKK Estimations – Crisis Period 1(August 2007 - August 2008)					
	Coeff	Signif		Coeff	Signif
Beta_EQi,j	-0.058	0.215	Gema_EQi,j	-0.210	0.594
Beta_EQj,i	0.115	0.264	Gema_EQj,i	-0.070	0.760
Beta_INDi,j	0.032	0.588	Gema_INDi,j	0.679	0.331
Beta_INDj,i	0.072	0.368	Gema_INDj,i	-0.608	0.054
Beta_FINi,j	-0.132	0.069	Gema_FINi,j	0.125	0.010
Beta_FINj,i	0.178	0.000	Gema_FINj,i	-0.272	0.035
Panel C: VAR - GARCH(1, 1)-BEKK Estimations – Crisis Period 2(September 2008 - December 2009)					
	Coeff	Signif		Coeff	Signif
Beta_EQi,j	-0.059	0.368	Gema_EQi,j	0.139	0.001
Beta_EQj,i	0.156	0.021	Gema_EQj,i	-0.017	0.000
Beta_INDi,j	0.011	0.860	Gema_INDi,j	0.101	0.003
Beta_INDj,i	0.066	0.148	Gema_INDj,i	-0.034	0.289
Beta_FINi,j	0.060	0.443	Gema_FINi,j	0.039	0.049
Beta_FINj,i	0.009	0.812	Gema_FINj,i	-0.008	0.762

We first look at matrix β in the mean equation, Eq. (1), captured by the parameters β_{ij}, in order to see the relationship in terms of returns across the countries and sectors in each pair. Next we examine the estimated results of the time-varying variance–covariance Eq. (4) in the system. The matrices *G (Gemma)* reported in Table 1-4 help examine the relationship in terms of volatility as stated in Eq. (4). The off-diagonal elements of matrices *G* capture the cross-market effects such as shock and volatility spillovers among the pairs.
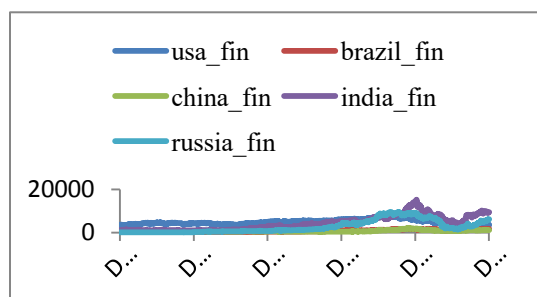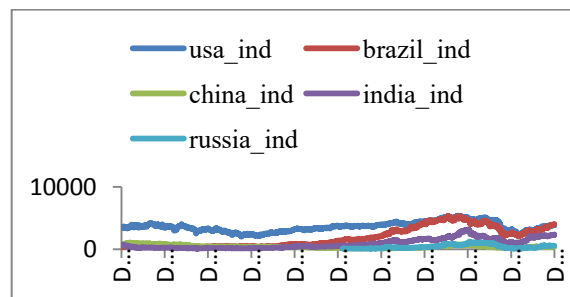
Figure 2: Financial Sector Development

Figure 3: Industrial Sector Development

Table 2 Volatility Spillovers between US and Russian Equity Markets and Their Industrial and Financial Sectors Estimated from a Bivariate VAR - GARCH(1, 1)-BEKK Model of Daily Return Indices

The diagonal and off diagonal elements in matrix Beta measures own and cross-market return effect and diagonal and off diagonal elements in matrix Gama measures own and cross-market GARCH effects. EQ represents equity markets, IND and FIN stands for industrial and financial sector of the equity markets respectively. i and j represent USA and Russia. Sample period is from January 2000 to August 2007 consisting of 1071 daily observations for pre crisis period. Crisis period is chosen between August 2007 and August 2008 and September 2008 till December 2009, representing before and after the collapse of Lehman Brothers.

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Pre Crisis

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	-0.011	0.257	Gema_EQi,j	0.052	0.005
Beta _EQj,i	0.293	0.000	Gema_EQj,i	0.004	0.442
Beta _INDi,j	0.008	0.284	Gema_INDi,j	1.767	0.000
Beta _INDj,i	0.299	0.015	Gema_INDj,i	0.025	0.033
Beta _FINi,j	-0.008	0.271	Gema_FINi,j	0.058	0.001
Beta _FINj,i	0.283	0.000	Gema_FINj,i	0.006	0.168

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Crisis Period 1(August 2007 - August 2008)

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	-0.044	0.379	Gema_EQi,j	-0.560	0.000
Beta _EQj,i	0.284	0.000	Gema_EQj,i	0.108	0.144
Beta _INDi,j	-0.076	0.016	Gema_INDi,j	0.265	0.000
Beta _INDj,i	0.225	0.014	Gema_INDj,i	-0.071	0.000
Beta _FINi,j	-0.188	0.004	Gema_FINi,j	-0.182	0.000
Beta _FINj,i	0.310	0.000	Gema_FINj,i	0.199	0.002

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Crisis Period 2(September 2008 - December 2009)

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	0.027	0.395	Gema_EQi,j	-0.121	0.021
Beta _EQj,i	0.299	0.003	Gema_EQj,i	0.036	0.020
Beta _INDi,j	-0.027	0.233	Gema_INDi,j	0.427	0.000
Beta _INDj,i	0.274	0.012	Gema_INDj,i	-0.072	0.000
Beta _FINi,j	0.067	0.053	Gema_FINi,j	-0.023	0.412
Beta _FINj,i	0.024	0.702	Gema_FINj,i	-0.006	0.731

Results are available from table 1-4. We divide our analysis in three parts, pre crisis (Jan. 2000 – Jul 2007), crisis period 1 (Aug 2007 – Aug. 2008), start of the world wide credit crunch in August 2007 but before the Lehman Brothers' bankruptcy in September 2008, crisis period 2 (Sep. 2008 – Dec. 2009) Lehman Brothers' bankruptcy in September 2008 till the end of 2009.

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Table 3 Volatility Spillovers between US and Indian Equity Markets and Their Industrial and Financial Sectors Estimated from a Bivariate VAR - GARCH(1, 1)-BEKK Model of Daily Return Indices

The diagonal and off diagonal elements in matrix Beta measures own and cross-market return effect and diagonal and off diagonal elements in matrix Gama measures own and cross-market GARCH effects. EQ represents equity markets, IND and FIN stands for industrial and financial sector of the equity markets respectively. i and j represent USA and India. Sample period is from January 2000 to August 2007 consisting of 1071 daily observations for pre crisis period. Crisis period is chosen between August 2007 and August 2008 and September 2008 till December 2009, representing before and after the collapse of Lehman Brothers.

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Pre Crisis

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	0.006	0.594	Gema_EQi,j	0.008	0.286
Beta _EQj,i	0.184	0.000	Gema_EQj,i	-0.012	0.008
Beta _INDi,j	0.011	0.392	Gema_INDi,j	0.000	0.936
Beta _INDj,i	0.136	0.000	Gema_INDj,i	-0.005	0.524
Beta _FINi,j	0.000	0.967	Gema_FINi,j	0.004	0.515
Beta _FINj,i	0.135	0.000	Gema_FINj,i	-0.005	0.144

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Crisis Period 1(August 2007 - August 2008)

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	-0.085	0.011	Gema_EQi,j	-0.090	0.670
Beta _EQj,i	0.450	0.000	Gema_EQj,i	-0.177	0.006
Beta _INDi,j	-0.061	0.053	Gema_INDi,j	0.266	0.048
Beta _INDj,i	0.316	0.000	Gema_INDj,i	-0.110	0.008
Beta _FINi,j	-0.133	0.001	Gema_FINi,j	-0.133	0.001
Beta _FINj,i	0.477	0.000	Gema_FINj,i	0.477	0.000

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Crisis Period 2(September 2008 - December 2009)

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	0.130	0.002	Gema_EQi,j	0.154	0.000
Beta _EQj,i	0.145	0.007	Gema_EQj,i	-0.099	0.000
Beta _INDi,j	0.088	0.088	Gema_INDi,j	0.133	0.000
Beta _INDj,i	0.132	0.023	Gema_INDj,i	-0.094	0.002
Beta _FINi,j	0.109	0.036	Gema_FINi,j	0.109	0.036
Beta _FINj,i	0.113	0.003	Gema_FINj,i	0.113	0.003

Our results exhibit direct linkage for both returns and volatility between the US equity market and the BRIC markets. For instance, in case of return spillovers, both crisis periods exhibit highly significant return spillovers from US market to all the BRIC countries markets and their sectors. Results for the pre crisis period shows that India and Russian equity returns as well as their financial and industrial sector returns were highly effected by the movements in US equity market and its financial and industrial sectors. Likewise, results for volatility establish clear evidence of contagion, at least in equity and industrial sector, however, only Russian financial sector found severely hit after the Lehman Brothers' bankruptcy. In addition, following prior research, to examine the long-term relationship among the markets we utilize Johansen cointegration test, (results available on request), and to examine the causality affects between two markets we apply Granger Causality test (results available on request) Both the conventional methods also support our results obtained by using multivariate GARCH- BEKK representation Moreover, one can argue that the so called "decoupling" theory does not hold true at least for the BRIC countries.

**Table 4 Volatility Spillovers between US and Chinese Equity Markets and Their Industrial and Financial Sectors
Estimated from a Bivariate VAR - GARCH(1, 1)-BEKK Model of Daily Return Indices**

The diagonal and off diagonal elements in matrix Beta measures own and cross-market return effect and diagonal and off diagonal elements in matrix Gama measures own and cross-market GARCH effects. EQ represents equity markets, IND and FIN stands for industrial and financial sector of the equity markets respectively. i and j represent USA and China. Sample period is from January 2000 to August 2007 consisting of 1071 daily observations for pre crisis period. Crisis period is chosen between August 2007 and August 2008 and September 2008 till December 2009, representing before and after the collapse of Lehman Brothers.

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Pre Crisis

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	0.006	0.657	Gema_EQi,j	0.006	0.143
Beta _EQj,i	0.027	0.287	Gema_EQj,i	0.010	0.003
Beta _INDi,j	0.003	0.850	Gema_INDi,j	0.000	0.943
Beta _INDj,i	0.017	0.453	Gema_INDj,i	0.008	0.003
Beta _FINi,j	0.007	0.522	Gema_FINi,j	0.002	0.706
Beta _FINj,i	0.043	0.136	Gema_FINj,i	0.010	0.090

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Crisis Period 1(August 2007 - August 2008)

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	-0.008	0.801	Gema_EQi,j	-1.324	0.000
Beta _EQj,i	0.470	0.000	Gema_EQj,i	-0.283	0.000
Beta _INDi,j	-0.043	0.182	Gema_INDi,j	0.304	0.092
Beta _INDj,i	0.257	0.036	Gema_INDj,i	-0.039	0.473
Beta _FINi,j	0.006	0.891	Gema_FINi,j	0.096	0.026
Beta _FINj,i	0.346	0.000	Gema_FINj,i	-0.072	0.063

Panel A: VAR - GARCH(1, 1)-BEKK Estimations – Crisis Period 2(September 2008 - December 2009)

	Coeff	Signif		Coeff	Signif
Beta_EQi,j	0.077	0.030	Gema_EQi,j	-0.036	0.032
Beta _EQj,i	0.222	0.000	Gema_EQj,i	0.020	0.282
Beta _INDi,j	0.076	0.075	Gema_INDi,j	-0.038	0.064
Beta _INDj,i	0.175	0.000	Gema_INDj,i	0.021	0.339
Beta _FINi,j	0.034	0.490	Gema_FINi,j	-0.007	0.499
Beta _FINj,i	0.094	0.001	Gema_FINj,i	-0.002	0.909

DIAGNOSTIC TESTS

We also estimate the Ljung-Box Q-statistic used to test the null hypothesis that the model is correctly specified, or equivalently, that the noise terms are random. We calculate both standardized and standardized squared residuals up to lag 24 for each modelled pair. Results show (not reported, available on request) no series dependence in the squared standardized residuals, indicating the appropriateness of the GARCH–BEKK model.

SUMMARY AND CONCLUSIONS

In this paper we have examined the linkage between US equity market and the fastest growing economies of the world, the BRIC countries (Brazil, Russian, India and China) equity markets, and the transmission of the US subprime crisis of 2007-2009 to BRIC countries. We use a bivariate GARCH-BEKK model proposed by Engle and Kroner (1995). By utilizing daily total return indices, four pair-wise models are estimated, namely, USA–Brazil, USA–Russia, USA–India, and USA–China. Additionally, in view of the fact that BRIC markets have strong links with the global economy through trade and financial channels; we examine the transmission of US subprime crisis to BRIC equity market's financial and industrial sectors to identify the extent of contagion. Eight bivariate models are estimated for sectoral indices, representing the financial and the industrial sectors in each market analysed. While analyzing the contagion effect of US Subprime crisis 2007-2009, we consider two crisis periods, crisis period 1 (Aug 2007 – Aug. 2008), start of the world wide credit crunch in August 2007 but before the Lehman Brothers' bankruptcy in September 2008, crisis period 2 (Sep. 2008 – Dec. 2009) Lehman Brothers' bankruptcy in September 2008 till the end of 2009.

We found evidence of direct linkage between the US equity market and BRIC markets, both in regards of returns and volatility, For instance, in case of return spillovers, both crisis periods exhibit highly significant return spillovers from US market to all the BRIC countries markets and their sectors. Results for the pre crisis period shows that India and Russian equity returns as well as their financial and industrial sector returns were highly effected by the movements in US equity market and its financial and industrial sectors. Likewise, results for volatility establish clear evidence of contagion, at least in equity and industrial sector, however, only Russian financial sector found severely hit after the Lehman Brothers' bankruptcy. In addition, following prior research, to examine the long-term relationship among the markets and sectors we utilize Johansen cointegration test and finally to examine the causality affects between the markets and sectors we apply Granger Causality Test. Both the conventional methods to identify interdependence also support our results obtained by using multivariate GARCH-BEKK representation. Moreover, we found no support for the decoupling view while investigating the fastest growing emerging markets, the BRIC countries.

Thus, within the context of the US subprime crisis, our results offers a better understanding of the nature of international interdependence during the crisis period which is very valuable for the international investors, multinational corporations and portfolio managers, who all are involved in minimizing and managing their financial risk exposure. Likewise, international transmission of stock market volatility can impact on corporate capital budgeting decisions, investors' consumption decisions, and other business cycle variables.

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