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Financial contagion in the BRIC countries during the 2007 global financial crisis : Evidence from Markov Switching and nonlinear causality approaches.

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ABSTRACT

We examine possible financial contagion versus only interdependence between the United Stated stock market (ground-zero country) and the BRIC (Brazil, Russia, India and China) stock markets during the 2007 subprime crisis. Two empirical approaches have been employed: (1) the traditional adjusted correlation approach of Forbes and Rigobon (2002) and (2) the nonlinear causality approach of Hiemstra and Jones (1994). We found strong evidence for the presence of contagion phenomena from the USA stock market to the India stock market when we use Forbes and Rigobon approach. Using nonlinear causality method, we detect a contagion phenomenon for the Brazil and China stock markets. For the Russia country there is no evidence for the presence of contagion phenomena using all methods.

INTRODUCTION

In the last few decades many emerging and developing countries have accelerated their financial integration on international markets in order to, at least, benefited from an increasing of economic growth and employment. Despite these benefits, many others effects of integration remains ambiguous. For instance, financial market liberalization increases the vulnerability of domestic's economies to international factors and news, particularly to reversals in international capital movements. Subsequently, large co-movements between assets prices across international stock markets increase portfolio volatility for domestic investment, see Gagnon and Karolyi (2006), and Karolyi and Stulz (1996). Several others studies have showed that integration generally increases the interdependence between economies and then transmit shocks across borders, see for example Bekaert and Harvey, (1997), Kaminsky and Reinhart (2000), Longin and Solnik, (1995, 2001) and Loretan and English, (2000).

From previous points, it appears that the measurement of cross-markets linkages and the assessment of changes in their interdependencies before, during and after crises may be crucial for decision makers such as portfolio managers, central bankers and regulatory authorities. As a consequence, it is important to distinguish between interdependence and contagion in stock markets in period of financial crises. While the first, interdependence term, is defined as the relationship that exists between stock market returns on average over the sample period, the second, contagion, is defined as a significant change in the transmission mechanism between stock markets in crisis times.

In fact, since 1990, the word financial market has characterized by the presence of several crises originated from one country and extended to a wide range of markets and countries in a way that was hard to explain that phenomena on the basis of only fundamentals changes. For example, the US subprime crisis of 2007 have been

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transmitted to several stock markets in other part of world and have leads that economies towards a declined period. During this period, the US financial system has suffered from an important recession caused by the subprime crisis and which has been transmitted to many countries via different channels like financial markets and trade.

Thus, testing between interdependence and contagion in financial markets remains one of the most important debates in empirical finance. Many theoretical and empirical works have examined this problem for different financial crises. Moreover, a multitude of statistical and econometrics tools have been used. Empirical results are also very mixed (King and Wadhwani 1990; Eichengreen *et al*. 1996; Forbes and Rigobon, 2002; Favero and Giavazzi, 2005; Syriopoulos, 2007; Gilmore *et al.*, 2008; Morana and Beltratti, 2008). Until now, no consensus has been reached about this question. Testing for interdependence and contagion remains a challenging task for several reasons. First, it appears that results depend on the used definition of the contagion concept. Second, traditional methods based on testing significant increases in correlation across-markets are not convincing and suffer from many limitations, see Calvo and Reinhart (1996) and Baig and Goldfajn (1998). Corsetti *et al*.(2005). Third, recent empirical literature that use nonlinear models to investigate contagion phenomena found also mixed results, see for instance Hamao *et al*. (1990), Edward and Susmel (2001) and Wang *et al*., (2006).

In this paper, we contribute to the literature in this field by investigating the question of interdependence *versus* contagion in the BRIC stock markets during the 2007 subprime crisis. First of all, we use a K-states of Markov switching model in mean and variance to date exactly the subprime crisis. Then, we propose to use two empirical methodologies to test for contagion versus only interdependence in the BRIC's countries during the Subprime crisis. For instance, in addition to the widely used traditional correlation approach and its adjusted version of Forbes and Rigobon (2002). Empirically, we apply these two methods to both tranquil and crisis periods. Then, for the cases of Forbes and Rigobon (2002) and Engle (2002) approaches we test for a significant increase in correlation between the two sub-periods. For the case of nonlinear causality, we distinguish between four possible cases two of them are for particular interests (the interdependence and the contagion cases). Our empirical finding shows evidence in the presence of contagion phenomena from the USA stock market to the India stock market when we use the two empirical methods. Using the nonlinear causality method we found evidence of contagion for the Brazil and China countries. For the Russia country there is no evidence for the presence of contagion phenomena.

The rest of the paper is organized as follows. Section 2 discusses the two concepts of contagion and interdependency. Section 3 presents the BRIC's countries and the Sub-prime crises. Section 4 describes the data, the traditional correlation approach, and the nonlinear causality approach. Section 5 discusses the empirical results and test for the presence of contagion or only interdependence. Finally, section 6 concludes.

Contagion versus interdependence literature review:

The empirical literature on contagious effects of financial crises continues to be the topic of academic research because of its important consequences for the global economy in relation to monetary policy, optimal ass*et al*location, risk measurement, capital adequacy, and asset pricing. Modeling the comovements of stock market returns is, however, a challenging task. Various empirical approaches have been used to investigate contagion versus interdependence during the financial crisis. These different approaches can be classified into the following categories. the conventional measure of market interdependence, known as the Pearson correlation coefficient, the adjusted correlation of Forbes and Rigobon, the dynamic conditional correlation, the regime switching models, the copulas analysis…etc.

The first methodology used to test the financial contagion is the cross-market correlation coefficients. This approach tests and compares the cross-market correlation during the pre-identified crisis period relative to the tranquil period. The contagion phenomenon occurs when the cross-market correlation during a crisis compared to a tranquil period increases. Empirical results about the existence of contagion based on correlation approach are not conclusive.For example, King and Wadhwani (1990) find a significant increase in the cross-country correlation coefficients of stock returns during the 1987 U.S. market crash among three markets of U.S., the U.K., and Japan. Similarly, Bertero and Majer (1990) and Lee and Kim (1993) find evidence of significant increase in correlation and conclude to the presence of contagion phenomena in their investigations of the 1987 U.S. stock market crash. Calvo and Reinhart (1996) find that correlations increased across weekly equity and Brady bond returns for emerging markets in Latin America during the turbulence period of the 1994 Mexican crisis. The contagion effect has been investigated during the 1997 Asian crisis by Baig and Goldfajn (1999), Khan *et al*. (2005), and Khan and Park (2009). They found evidence of increased cross-market correlations. For example, Baig and Goldfajn (1999) by using the correlation analysis test the presence of contagion in the equity, currency and money markets in emerging economies during the Asian financial crisis. Their result show that correlations in currency and sovereign spreads increased significantly during the crisis period, whereas equity market correlations offered mixed evidence.

However, testing for significance increase in correlation before and during crisis periods using traditional correlation approach suffers from several limitations. First, there is a problem of heteroskedasticity when high frequency data are used. More precisely, the estimated correlation coefficients during the crisis period are in general upwardly biased, and hence a test based on the biased correlation would imply spurious contagion. To resolve this issue, Forbes and Rigobon (2002) suggest an adjustment for the correlation coefficient during the turmoil period. Using adjusted correlation from heteroscedasticity, the authors found no increase in correlation coefficients during the East Asian crisis, Mexican crisis, and 1987 U.S. market crash among 29 nations including 9 in Southeast Asia, 4 in Central and South America, 12 in OECD, and four other new nations. Instead, they found a continued high level of correlation in more tranquil periods and thus concluded that these crises are not the result of contagion but rather of interdependence. Moreover, Corsetti *et al*. (2005) stress that the significant increase in adjusted correlation is not explained by the behavior of the common factors and the country-specific factor. This implies the generation of new temporary channels of shocks propagation, in addition to the permanent channels, which characterizes the interdependence between economies. Second, there is a problem of omitted variables such as fundamentals variables. Third, contagion must involve evidence of a dynamic increment in the regressions, affecting at least in the second moment's correlations and covariance.

In the empirical analysis of contagion the conventional econometric techniques including cointegration, causality tests and univariate ARCH and GARCH models has been also used. The empirical result shows strong evidence in favor of cross-market volatility spillover and in particular from the crisis country to other economies (Hamao *et al*. 1990, Chakrabarti and Roll 2002, Diebold and Yilmaz 2009). For example, Hamao, Masulis, and Ng (1990) investigate the correlation between three markets volatilities during the 1987 US stock market crisis. They apply the conditional variance estimated under the GARCH model and found that the spillover effects from New York to London and Tokyo and from London to Tokyo were observed among the stock markets in New York, London, and Tokyo. Additionally, Diebold and Yilmaz (2009) find evidence of divergent behavior in the dynamics of return spillovers vs. volatility spillovers from the early 1990s to the 2000s. Several empirical studies have used causality test to investigate the interdependence and the contagion of financial crises. For example, Gomez-Puig and Sosvilla-Rivero (2011) apply the Granger causality test for European Monetary Union (EMU) during different period since. Their results show the presence of contagion phenomenon around the first year of EMU in 1999, the introduction of euro coins and banknotes in 2002, and the global financial crisis in the late-2000s. Furthermore, they detect a contagion between EMU countries caused by the crises in sovereign debt markets from 2009.

In the same vein, Gelos and Sahay (2001) using Granger causality tests studied contagion effects in the economies of Central and Eastern Europe, Russia and the Baltic since 1993. The results suggest that after the Russian crisis of 1998, the movements of the European emergent markets were similar to the movements observed in many Asian and Latin American markets during the Asian crisis. The shocks originating from the Russian shares market caused the movements in the markets of the Czech Republic, Hungary and Poland in a Grangerian sense. The authors rejected the hypothesis that there was contagion originating from the markets of the Czech Republic, Asia and Russia, in the direction of the European financial markets. The causality test has been used by Masih and Masih (1999) to investigate the contagion between 4 stock markets of Southeast Asia and four industrialized markets. The results show the existence of contagion in Southeast Asia countries in particular the importance of the role played by Hon Kong in this contagion. Similarly, Khalid and Kawai (2003) applied the Granger causality test to identify the existence of the contagion phenomena or interdependence during the Asian crisis for 9 Asian countries. Their results were not support for the contagion.

This first generation of analysis has been followed by other methodologies, such as the dynamic conditional correlation, the regime switching models, the copulas analysis. This new generation offers additional efficient tools in testing contagion and/or interdependence between stock markets.

In the area of Markov Switching ARCH model (SWARCH) of Hamilton and Susmel (1994), and copula with extreme value theory several empirical studies tested the evidence of contagion during the financial crisis. For the case of SWARCH model, the intensity of co-movement between stock market varies under high and low volatility regimes. This model resolves the problem encountered when employing GARCH models, which are highly sensitive to regime changes. The issue in the GARCH models is that the results obtained might not be consistent during periods of low/high volatility. By employing the SWARCH model, Edwards and Susmel (2001) found evidence of volatility co-movement across Latin American markets during the crisis in the 1990s, but no volatility dependence between Hong Kong and Latin American markets using both univariate and multivariate techniques. Moreover, Boyer *et al*. (2006) demonstrated that there is greater co-movement during high volatility periods for numerous accessible and inaccessible stock indices using both regime switching models and extreme value theory. Canarella and Pollard (2007) found that each high volatility episode appears to be associated with either a local or an international financial crisis by applying the SWARCH model to some Latin American countries. By using a SWARCH-L model for four Latin American stock markets (Argentina, Brazil, Chile, and Mexico) Diamandis (2008) founded the existence of multiple volatility regimes and a significant increase in volatility during the Mexican, Brazilian, and Asian crises. Moreover, in order to test the

contagion effects between the U.S stock market and some MENA stock markets Khallouli and Sandretto (2012) use the Markov-Switching EGARCH. The results of their estimations show that the financial crisis in the USA has been transmitted to MENA stock markets. They interpret this situation as evidence of mean and volatility contagion. Particularly, they have found mean and volatility contagion in the Bahrain and Egypt stock markets. In the case of Morocco and Turkey the authors reveal a mean contagion, while the contagion to Oman and Dubai is explained only by the US volatility.

Regarding the copulas method, Patton (2006) initiated the analysis of time varying copulas for modeling asymmetric exchange rate dependence. This method has been applied in finance to test the evidence of contagion effects (see, Cherubini 2004). Employing extreme value copula functions, De Melo Mendes (2005) examine the dependence of returns for seven emerging countries markets. His result show the existence of asymmetry in the joint co-exceedances for the most 21 pairs of markets considered and a strong dependence in cross market tail during bear market. Similarly, Caillaut and Guegan (2005) use the copulas approach to check the dependence between markets of Thailand, Indonesia and Malaysia from July 1987 to December 2002. The analysis of daily data shows a symmetric dependence for Thailand-Malaysia pair but an asymmetric dependence for Indonesia-Thailand and Malaysia-Indonesia pairs.Samitas and Tsakalos (2013) investigate the relationships between the Greek stock market and seven European stock markets and use copula functions to measure financial contagion. The results of their study provide support to the contagion phenomenon despite the lower than expected impact. By employing a multivariate copula approach Aloui *et al*. (2011) use daily return data from BRIC markets to study its links with the US market during the period of the global financial crisis. They find that dependency on the U.S. is higher and more persistent for Brazil–Russia than for China–India.

BRIC Economies and Subprime crisis:

BRIC countries in globalization process:

BRIC countries represent actually a particular interest for financial investors and economists. These economies are expected to record for the thirty next year a highly potential economic growth and become an economic and financial power. Recently, the BRIC have largely contributed to the world GDP growth. According to various economists' projections, it is only a matter of time before China becomes the biggest economy in the world - sometime between 2030 and 2050 seems the consensus. In fact, Goldman Sachs believes that by 2050 these will be the most important economies, relegating the US to fifth place. By 2020, all of the BRIC countries should be in the top 10 largest economies of the world. The undisputed heavyweight, though, will be China, also the largest the creditor in the world.

The graph one below, describes the GDP growth of BRIC countries over the crises period from 2002 to 2008. For example, the GDP growth in China is equal to 10% per annum. Similarly, this variable grew in average by 8% annually in India. However, the crisis started in the USA has affected the economic performance of these four countries as a new large economic power in the world. Thus, the crisis has affected Russian economy and the country see its growth contracted by 8% in 2008, Brazilian – by 0,3%, losing more than 5 p. P since 2007, Chinese output growth has lost over 5% since the beginning of the crisis, and India has shown almost the same results as China.

Graphics 3 and 4 show the trend in the inflow of foreign direct investment in these countries over the same period. Due to various reasons this trend is reversed. In 2008, Russia lost 12 billion USD of FDI, while Brazil watched 20 billion USD make a quick exit from their economy. The corresponding figure for India was a little under 1 billion USD.In these countries the rapid economic growth is in part explained by a steady rise of FDI. Brazil, Russia, India and China have seen a steady rise in FDI in a wide range of sectors. The onset of the global crisis meant the growth rate of FDI plummeted. According to the estimations of the World Bank, Russia, in particular, will be able to reach the pre-crisis level only in 2014.

The period of crisis has also affected the global trade of BRIC countries. The recession of the trade as a whole has damaged the economies of export-oriented China and Brazil. For the countries domestic-demand oriented, like India, the global recession did not hit it so much. The first countries, China, Russia and Brazil taken a decision to promote exports of goods and commodities and increases its share, other countries the share of export in GDP was quite low. The crisis in this case will contract the global economy and consequently the economies of China, Russia and Brazil. India, on the other hand, weathered the crisis. Of course, as already mentioned, the contraction of the global economy was not the only factor, but one of the most significant ones.

Tarzi (2000, 2005) studied the flow of foreign portfolio equity investments and foreign direct investment to emerging markets between 1986 and 1995 and reported that stock market capitalization in emerging countries grew from $171 billion to 1.9 trillion and the market share held in capitalization increased from 4% to 11%, mostly attributed to the BRICs.

Apart from their growth characteristics, the BRIC grouping was not based on economic similarities. However, for international business and trade purposes, the four countries are vastly different. India and China are peasant economies with relatively closed, state-controlled, regulated capital markets; Brazil and Russia are primarily natural resource– based economies that are open to foreign trade and financial flows, and have a

mixture of state and private sector control of capital markets. The first subgroup (China and India) has guided its exchange rate (more in China than in India), while the second subgroup has more flexible exchange rates. India and China practice development strategies based on domestic industrialization (manufacturing and services) for export, while Brazil and Russia follow export strategies in directing productive structures that are guided by international comparative advantage. While this latter subgroup has experienced exchange rate and financial crises that were usually accompanied by high inflation, the former subgroup has not.

Subprime crises:

The last episode of turbulence triggered by the subprime mortgage crises in the United States could have affected stock volatility. This crisis transmitted rapidly to other financial market is due to asymmetric information resulting from the complexity of the structured mortgage products and, subsequently, as a result of a more widespread reprising of risk which may have taken the form of a decrease in global investors risk appetite (see Gonzalez-Hermosillo (2008)). These events resulted in the most by a collapse of the banking industry, stock market crashes and a large decrease in liquidity on the credit market. In the early stages of the crisis, the securities backed with subprime mortgages held by many financial institutions rapidly lost most of their market value because of a dramatic rise in these mortgages' delinquencies and foreclosures in the United States. This led to the reorganizations, liquidations, and government bailouts of major U.S. financial institutions (e.g., Bear Stearns, Lehman Brothers, and the American International Group) because their capital largely vanished.

The major feature of the U.S. subprime crisis is its rapidly propagation, spilling over into not only other sectors of the economy but also other countries. This propagation of crisis takes the form of a dramatic decline in the value of equities markets and commodities worldwide. The successive failures of bank in US, such as Lehman Bankruptcy, triggered this transmission of such impact to other markets.

Some research confirms this observation like the increase of volatility of Turkey price indice (ISE-100) after the bankruptcy of Lehman Brothers, see Celikkol *et al*. (2010). Longstaff (2010) find that there was financial contagion spillover across to other financial markets as the Subprime crisis developed. Ramlal (2010) find that volatility clustering had increase and interpret this result by the existence of transmission effect of subprime crisis to other emerging countries. Moreover, he shows that leverage effects are higher in crises period compare to pre-crisis period in most of stock markets.

Empirical methodology:

In this paper, we employ three different econometrics and statistical approaches to examine the existence of stock market contagion during the subprime crisis from the U.S stock market to the four BRICs countries. In contrast to other previous study and to date exactly the break date, we use a K-states Markov switching model with both changes in mean and in variance. In addition, as a starting point of our empirical approach, we use the adjusted correlation approach proposed by Forbes and Rigobon (2002, 2003), the multivariate DCC-EGARCH model as in Chiang *et al*. (2007) and Syllignakis and Kouretas (2001) and the for nonlinear causality between the U.S stock market and each BRIC stock market. For all three approaches, we investigate the behavior of the statistic of interest, the adjusted correlation or the nonlinear causality test, for both tranquil and crisis periods.

The rest of this section is organized as follow.First, in subsection 4.1., we present the Markov switching model with two states in variance. Second, in subsection 4.2., we present the adjusted correlation approach as developed by Forbes and Rigobon (2002, 2003). Finally, in subsection 4.4. We present how we adapt the nonlinear causality approach proposed by Hiemstra and Jones (1994) to test for contagion versus interdependence.

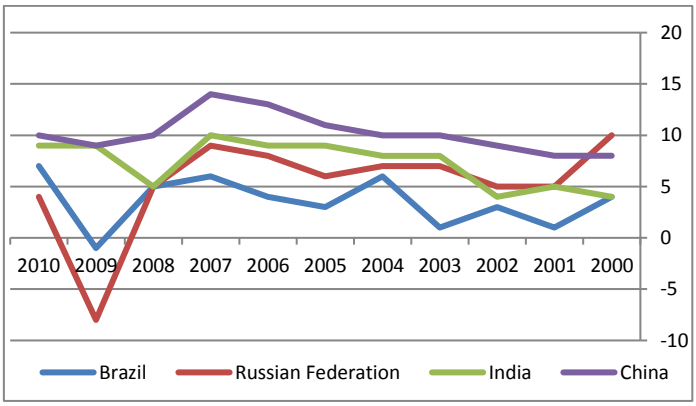

Fig. 1: GDP Growth (annual %)

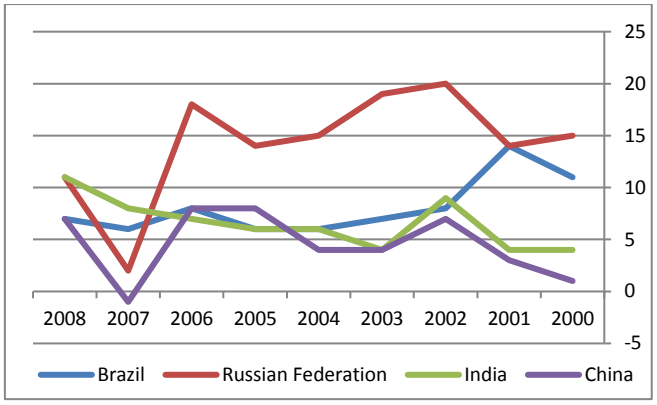

Fig. 2: Inflation, GDP deflator (annual %)

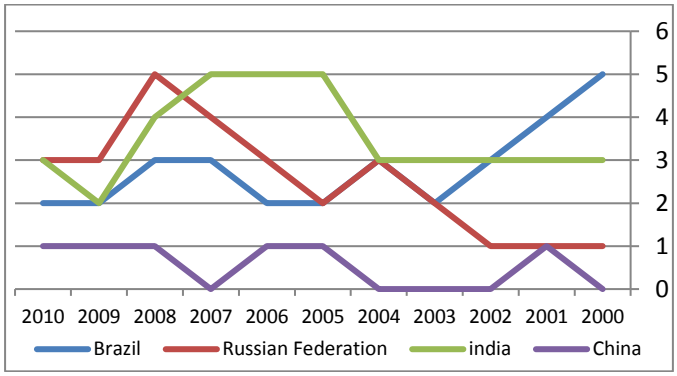

Fig. 3: Foreign direct investment, net inflows (% of GDP)

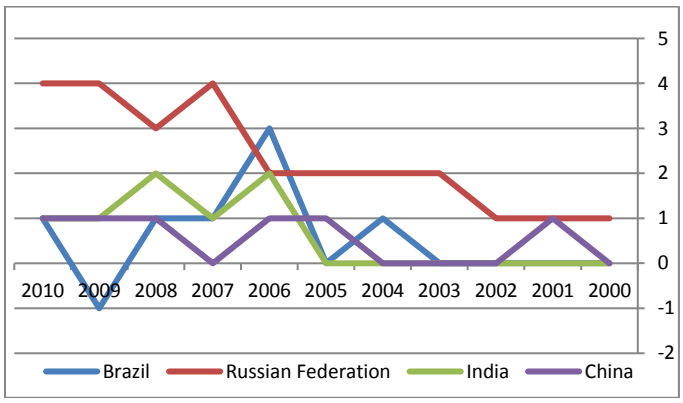

Fig. 4: Foreign direct investment, net outflows (% of GDP)

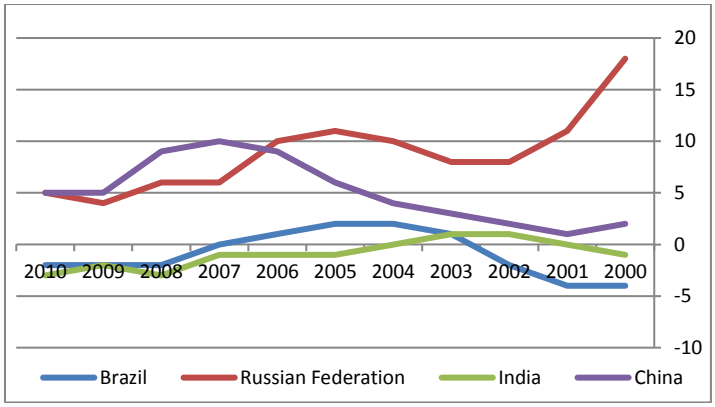

Fig. 5: Current account balance (% of GDP)

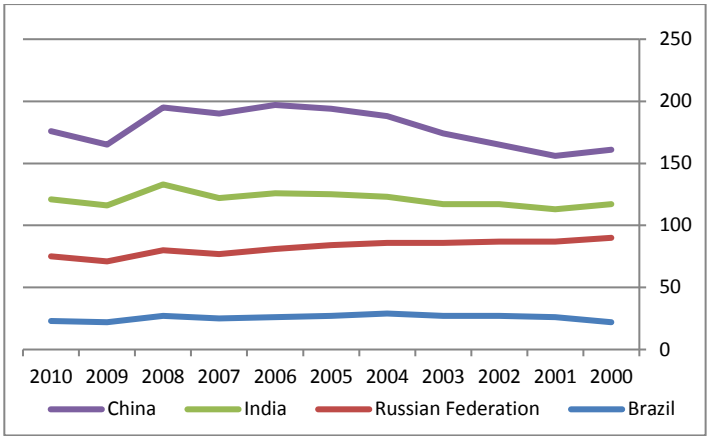

Fig. 6: Trade (% of GDP)

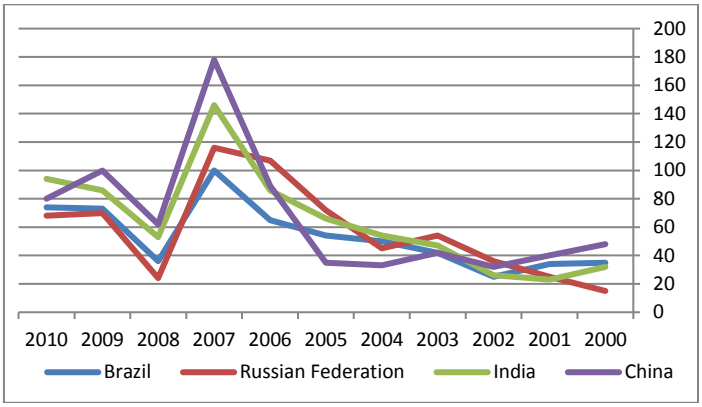

Fig. 7: Market capitalization of listed companies (% of GDP)

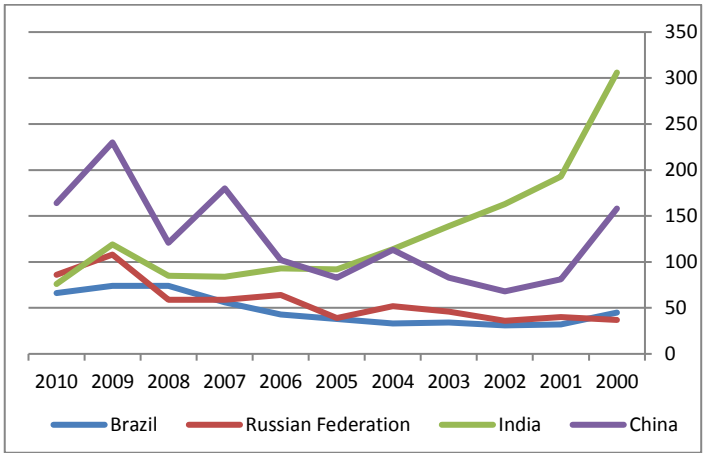

Fig. 8: Stocks traded, turnover ratio (%)

K-states Markov Switching model:

To date the subprime crisis we use a K states Markov switching model with changes in means and variances. The model is given by,

$r_t = \alpha_{S_t} + \sigma_{S_t}\varepsilon_t$

Where $\varepsilon_t \sim N(0,1)$.

Where r_t is the U.S stock market return and α_1, α_2, α_3, …, $\alpha_m$are the estimated coefficients of the mean equation. σ_{S_t} is the standard deviation which depend on the state of the stock markets. We estimate here all Markov switching models until the loglikelihood ratio test show that the alternative model is rejected.

The mean and variance equations are defined by,

Mean-equation :

$\alpha_{S_t} = \alpha_1 S_{1t} + \alpha_2 S_{2t} + \cdots + \alpha_m S_{mt}$

Variance-equation :

$\sigma^2_{S_t} = \sigma^2_1 S_{1t} + \sigma^2_2 S_{2t} + \cdots + \sigma^2_m S_{mt}$

$S_{kt} = 1$ if $S_t = k$, and $S_{kt} = 0$ otherwise; $k = 1,2,3,4,\ldots,m$

The of regime is governed by a first order three states Markov chain given by,

$p_{ij} = P[S_t = j | S_{t-1} = i]$for $i, j = 1, 2, 3, \ldots, k$and $\sum_{j=1}^{k} p_{ij} = 1$

In addition, we suppose that $\sigma_1^2 < \ldots < \sigma_m^2$. For example for the case of three states Markov switching model, σ_1 corresponds to the low volatility state, σ_2 to the medium volatility state and finally σ_3 to the high volatility state.

Correlation analysis:

Forbes and Rigobon (2002) and Rigobon (2003) define shift contagion by the significant rise in cross-market interdependencies. In order to explain the phenomenon of contagion, this paper builds from, Forbes and Rigobon (2002) model given by,

$r_{it} = \mu + \beta\, r_t^{US} + \varepsilon_t$ (1)

Where r_{it} is the returns of country $i =$ (, Brazil, Russia, India, China), r_t^{US} is the returns ground zero country which is the U.S in our study. μ and β are the coefficients to estimate of the model. $\varepsilon_t$is the error term.

The adjusted correlation coefficient proposed by Forbes and Rigobon (2002) is given by,

$\rho^* = \frac{\rho}{\sqrt{1+\delta(1-\rho^2)}}$ (2)

Where ρ is the unadjusted correlation coefficient supposed to vary with period of low volatility (before crisis period) and period of medium-high volatility (during crisis period). This correlation coefficient is given by,

$\rho = \frac{cov(r_{it}, r_t^{US})}{\sqrt{Var(r_{it})Var(r_t^{US})}} = \left[1 + \frac{Var(r_{it})}{\beta^2\, Var(r_t^{US})}\right]^{-1/2}$ for $i =$ (, Brazil, Russia, India, China) (3)

And δ is a measure of the relative increase in the observed variances of the stock market returns variabler_t^{US}. The quantity δ is defined by $\delta = \frac{Var(r_t^{US})^{crisis}}{Var(r_t^{US})^{tranquil}} - 1$, where$\mathrm{Var}(\mathrm{r_t^{US}})^{\mathrm{crisis}}$ and $\mathrm{Var}(\mathrm{r_t^{US}})^{\mathrm{tranquil}}$ are the variances, during the crisis and the tranquil periods, respectively.

To test for the presence of contagion between the country source of crises, the USA here, and each of the BRIC countries, we use the student test based on the differences between correlation coefficients. Hence, a statistical analysis of contagion versus interdependence can be performed using the two hypotheses:

$\begin{cases} \boldsymbol{H_0}: & \rho^*_{tranquil} = \rho^*_{crisis} \text{ (interdependence)} \\ \boldsymbol{H_1}: & \rho^*_{tranquil} \neq \rho^*_{crisis} \text{(pure contagion)} \end{cases}$

Where, $\rho^*_{tranquil}$ is the correlation coefficient between returns (r_{it}) of country *i* and returns (r_t^{US}) during the tranquil period.

$\rho^*_{crisis}$is the correlation coefficient between returns (r_{it}) of country *i* and returns (r_t^{US}) during the crisis period. To test for significance increase in adjusted correlations, we use a Student test as suggested by Collins and Biekpe (2002). This test is given by,

$$\boldsymbol{t} = \left(\rho^*_{crisis} - \rho^*_{tranquil}\right)\sqrt{\frac{\boldsymbol{n_{tranquil}} + \boldsymbol{n_{crisis}} - \mathbf{2}}{\mathbf{1} - \left(\rho^*_{crisis} - \rho^*_{tranquil}\right)}}$$

This $\boldsymbol{t}$ statistic follows under the null hypothesis of interdependence a student distribution with $\left(\boldsymbol{n_{tranquil}} + \boldsymbol{n_{crisis}} - \mathbf{2}\right)$degrees of freedom, where $\boldsymbol{n_{tranquil}}$ and $\boldsymbol{n_{crisis}}$are the number of observations under the tranquil and crisis periods, respectively.

The decision rule is as follows. If there is no a significant difference between$\rho^*_{tranquil}$ andρ^*_{crisis}, then there is no evidence for the presence of contagion. Conversely, if an opposite result is obtained when testing for the significant difference between $\rho^*_{tranquil}$ and ρ^*_{crisis}, then we conclude that there is a pure contagion between the country origin of crises (USA here) and the corresponding BRIC country.

Nonlinear causality tests:

The third method considered in this paper to test for the presence of contagion or interdependence phenomena between the USA and the BRIC countries is nonlinear causality tests. This method is proposed by Baek and Brock (1992) which offer a nonparametric statistical method to detect nonlinear causal relations. This method basically relies on the assumption that the variables are mutually independent and identically distributed. However, this assumption seems to be quite restrictive as it eliminates the time dependence of variables and does not consider the nature and range of the dependence. Hiemstra and Jones (1994) modify the Baek and Brock (1992)'s test to allow the testing variables to exhibit short-term temporal dependence. By

defining the m-length lead vector of Y_t noted Y_t^m , and the Ly-length and le-length lag vectors of Y_t and X_t, respectively, by $Y_{t-L_y}^{L_y}$ and $X_{t-L_e}^{L_e}$, we obtain the following representations (Hiemstra and Jones, 1994),

$Y_t^m = (Y_t, Y_{t+1}, \dots, Y_{t+m-1}), \quad m = 1,2, \dots, t = 1,2, \dots$

$Y_{t-L_y}^{L_y} = \left(Y_{t-L_y}, Y_{t-L_y+1}, \dots, Y_{t-1}\right), \quad L_y = 1,2, \dots, t = L_y + 1, L_y + 2, \dots$

$X_{t-L_e}^{L_e} = \left(X_{t-L_e}, X_{t-L_e+1}, \dots, X_{t-1}\right), \quad L_e = 1,2, \dots, t = L_e + 1, L_e + 2, \dots$

The definition of nonlinear Granger non causality is then given by

$$\Pr\left(\|Y_t^m - Y_s^m\| < \epsilon \left\|Y_{t-L_y}^{L_y} - Y_{s-L_y}^{L_y}\right\| < \epsilon \|X_{t-L_e}^{L_e} - X_{s-L_e}^{L_e}\| < \epsilon\right) = \Pr\left(\|Y_t^m - Y_s^m\| < \epsilon \left\|Y_{t-L_y}^{L_y} - Y_{s-L_y}^{L_y}\right\| < \epsilon\right), \quad (1)$$

Where Pr{.} is probability and ‖‖is the maximum norm. If Eq. (1) holds for given values of m, Ly and Le ≥ 1 and for $\epsilon > 0$, then $\{X_t\}$ does not strictly Granger cause $\{Y_t\}$. the Hiemstra-Jones test consists of choosing a value of ϵ whose typical values are between 0.5 and 1.5 after normalizing the series to obtain unit variance, and to test subsequently Eq. (1) by estimating the conditional probabilities as ratios of unconditional probabilities.

Hiemstra and Jones (1994) show that under Granger non causality the null hypothesis formulated by Eq. (1), the following statistic follows an asymptotic normal distribution as:

$$\sqrt{n}\left(\frac{C1(m+L_y, L_e, \epsilon, n)}{C2(m+L_y, \epsilon, n)} - \frac{C3(m+L_y, \epsilon, n)}{C4(L_y, \epsilon, n)}\right) \sim AN(0, \sigma^2(m, L_y, L_e, \epsilon)) \quad (2)$$

where n = T +1 − m − max(Ly, le), C1(m + Ly, Le, ϵ, n), C2(m + Ly, ϵ, n), C3(m + Ly, ϵ, n), and C4(Ly, ϵ, n) are correlation-integral estimators of the point probabilities corresponding to the left hand side and right hand side of Eq. (1). The test statistic in Eq. (2) is applied to the estimated residual series from the bivariate VAR model. The VAR models remove any linear predictive power and therefore the remaining incremental predictive power of the one series for another is an indication of the nonlinear predictive power.

The hypotheses of interest are,

H_0: there is no Granger causality from the USA to country *i*.

H_1: presence of Granger causality from the USA to country *i*.

Where *i* takes respectively the Brazil, Russia, India and China countries. To test for the presence of interdependence or contagion we should compare between the nonlinear test results between the tranquil period and the crises period. Four cases can arise,

In practice, only the first, third and fourth cases are of interest and can hold. The second case is not of particular interest and rarely hold in practice. This can be due to the low probability of occurrence of nonlinear causality in tranquil periods and its absence in crises periods.

The two cases of interest are the first and the third cases. The first case correspondents to the case of a simultaneous presence of nonlinear causality in the tranquil and crises period (H_1 holds for the two sub-periods). This case is characterized by a significant correlation between stocks markets before and during the subprime crises. In general, the correlation increases in crises period compared to tranquil periods but the increases is not significantly different from zero. This result can be interpreted as presence of interdependence. The third case correspondents to the case where the tranquil period is characterized by the absence of nonlinear causality (H_0 holds) and the presence of nonlinear causality in the crises period (H_1 holds). This third case is considered as the contagion case.

Finally, the fourth case is characterized by the absence of a simultaneous nonlinear causality. This case correspondent to the case of absence of dependence between the USA and the BRIC stocks markets.

Empirical results:

Descriptive analysis:

The data used in this paper consists of the daily indices denominated in US dollars, for four BRIC's countries named the Brazil, China, India, Russia, and USA countries. The sample covers the period from February 10, 2005 through April 14, 2009. The data were taken from the Morgan Stanley Capital International data set. We limit our sample to this period in order to account for only the period of the subprime crisis and the period after the subprime crisis.

An important step before testing for the presence of significance increase in correlations between the tranquil and crises periods is to date exactly the tranquil and crises periods.

A misspecification on determining these periods lead to a bias in the results. To this end, we use a two states Markov switching specification with only changes in variance where the high volatility state corresponds to the crisis period and low volatility state corresponds to the tranquil period. According to the selected specification, the tranquil period range from February 10, 2005 to July 13, 2007 and the crisis period is from July 14, 2007 to 14 April, 2009. The break point that separates between the tranquil period and the crises period is obtained using the smoothed probabilities of the Markov switching specification.

Descriptive statistics and unit roots tests results are reported in Table (1) and (2). Table (1) presents information on the mean, standard deviation, skewness coefficient, Kurtosis coefficient, the Jarque–Bera Normality test (JB), and Ljung–Box test (LB) for the level and squared series for the tranquil, crises and total periods.

Table (1) also shows that all series are non-normally distributed, as suggested by the two statistics, skewness and Kurtosis, and summarized by the JB test results. This behavior is largely observed on financial time series. Moreover, the high value of the kurtosis coefficient is also typical of high frequency financial time series, and is behind the rejection of normality. In addition, the Ljung–Box LB statistics for the level and squared series suggest significant autocorrelation except for the china return series in the level. The high dependence in the squared returns series indicates the presence of ARCH effects.

Comparing the descriptive statistics of the three periods, we remark that the mean return is positive during the tranquil period and negative during the crises period. Moreover, the variance is more pronounced in the crises period compared to the tranquil and total periods. This is expected because during crises periods investors generally sell stocks in order to reduce losses, then price fall and returns on these stocks markets will be negative. Crises period is also characterized by a higher level of variance due to the instability that characterize this period.

To test the stationary of the stock markets indexes, we have carried out the ADF, PP and KPSS unit roots tests. Empirical results for all the BRIC countries are reported in the table (2) below. In our cases neither the trend nor the intercept are significant. Following this table, the stock markets indices series are not stationary in level, but they are in first difference.

Table 1: Returns descriptive statistics using the wholes ample.

	Tranquil period					Crises period					Total period				
	USA	Brazil	Russia	India	China	USA	Brazil	Russia	India	China	USA	Brazil	Russia	India	China
Mean	0.042	0.168	0.152	0.144	0.157	-0.1	-0.08	-0.2	-0.12	-0.08	-0.03	0.059	-0.006	0.023	0.050
Median	0.065	0.265	0.180	0.237	0.115	0.003	0.017	-0.05	0.000	0.006	0.045	0.231	0.097	0.105	0.073
Std. Dev.	0.652	1.848	1.854	1.451	1.251	2.25	3.823	4.014	2.810	3.208	1.541	2.857	2.966	2.138	2.290
Skewness	-0.27	-0.519	-0.713	-0.545	-0.35	-0.3	-0.21	-0.26	-0.30	0.119	-0.23	-0.39	-0.513	-0.500	-0.021
Kurtosis	4.804	4.398	8.235	6.446	5.538	7.19	7.029	13.21	4.366	5.334	13.9	10.01	19.51	6.383	8.929
Jarque-Bera	93.55	79.64	773.0	343.1	182	336	313.4	1995	42.70	105.1	5395	2242	12329.	560.6	1583
LB(12)	15.40	21.87	19.58	15.84	8.567	27.2	16.6	50.14	24.34	9.526	57.31	23.93	69.504	44.65	17.635
$LB^2(12)$	47.78	104.3	199.7	417.5	37.86	388	456	203.2	142.7	219.9	1294.	1279	577.55	683	875.2
Observation	631	631	631	631	631	458	458	458	458	458	1089	1089	1089	1089	1089

The stable period is from10/2/2005to12/07/2007.The crisis period is from13/07/2007–14/04/2009.These two periods are detected using a two states Markov switching specification with only changes in variance. In that case state with low volatility corresponds to stable period and state with high volatility corresponds to the period of the subprime crises

Table 2: ADF, PP and KPSS unit roottests

	Tranquil period						Crises period						Total period					
	Level			First difference			Level			First difference			Level			First difference		
	AD	FPP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS
USA	-0.16	0.31	2.67	-26.20	-27.05	0.15	-0.42	-0.49	2.25	-18.74	-18.73	0.09	-1.01	-10.3	0.02	-28.42	-28.45	0.17
Bresil	-0.34	-0.13	2.64	-22.37	-22.22	0.08	-0.97	-0.95	1.53	-20.91	-20.91	0.16	-1.72	-1.70	20.25	-32.36	-32.38	0.05
Russia	-1.35	-1.36	2.61	-25.31	-25.31	0.12	-0.63	-0.56	1.96	-18.80	-18.71	0.19	-1.31	-1.34	1.45	-31.22	-31.22	0.19
India	-0.25	-0.27	2.81	-23.50	-23.48	0.05	-0.49	-0.54	2.17	-19.39	-19.39	0.23	-1.57	-1.58	0.66	-31.52	-31.53	0.170
China	1.09	1.09	2.48	-23.79	-23.76	0.25	-0.97	-0.95	2.17	-21.28	-21.28	0.13	-1.77	-1.81	1.43	-33.32	-33.36	0.19

Critical value at the 5% level of significance is equal to are -1.941 for the ADF and Phillips and Perron (PP) tests and equal to for 0,463 the KPSStest

Markov switching results:

The results of the estimation of the linear, two states, three states and four states Markov switching models are reported in Table 3 below. The likelihood ratio test is used to select the more appropriate model. At this level it is very important to mention that this test does not has the usual khi-squared distribution. To overcome this problem, we adopt the Davies (1977) bound and the Garcia (1998) critical values in addition to the usual

information criteria show that the three state Markov Switching specification is more appropriate than the linear, two states and also the four state specifications. This result is confirmed by the AIC and SC information criteria's which indicate that the three states specification describe better the evolution of the US stock market evolution.

Table 3: Estimation of the linear and Markov Switching models

	LinearModel		1 statesMS Model		2 statesMS Model		3 statesMS	
Parameters	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
α_1	-0.031	-0.664	0.044	1.75	0.054	2.39	0.068	2.801
α_2	-	-	-0.086	-2.83	-0.100	-3.24	-0.069	-1.154
α_3	-	-	-	-	-0.059	-1.92	-0.478	-0.459
α_4	-	-	-	-	-	-	-0.177	-0.473
σ_1	1.543	16.56	0.679	30.3	0.529	24.1	0.529	27.84
σ_2	-	-	2.593	21.2	1.199	22.8	1.206	25.68
σ_3	-	-	-	-	3.338	17.7	4.766	4.559
σ_4	-	-	-	-	-	-	2.748	10.215
p_{11}	-	-	0.987	56.43	0.985	14.10	0.985	164.2
p_{13}	-	-	-	-	0.014	-	0.014	2.312
p_{14}	-	-	-	-	-	-	0.000	-
p_{21}	-	-	-	-	0.015	23.45	0.016	2.072
p_{22}	-	-	0.973	83.6	0.982	13.56	0.982	122.7
p_{24}	-	-	-	-	-	-	0.002	1.925
p_{31}	-	-	-	-	0.000	-	0.000	-
p_{32}	-	-	-	-	0.024	0.434	0.000	-
p_{34}	-	-	-	-	-	-	0.000	-
p_{41}	-	-	-	-	-	-	0.000	-
p_{42}	-	-	-	-	-	-	0.000	-
p_{44}	-	-	-	-	-	-	0.638	1.936
LL	-2120.26		-1611.25		-1531.60		-1528.3	
LR test			1018.02		159.3		6.6	
AIC	3.707		2.976		2.829		2.831	
SC	3.716		3.003		2.870		2.886	

Probability smoothing results show that low volatility regime last two years (509 days), the medium volatility regime last for 419 days and the high volatility regime for 161 days.

As in this paper we consider two periods to investigate significant increase or presence of nonlinear causality between the tranquil and crisis period. Thus we consider that the low volatility period corresponds to the period before crisis and the two others periods (medium and high volatility) correspond to the period of subprime crisis.

Based on this result, the probabilities smoothing shows that the date of the beginning of the subprime crisis corresponds to 12/07/2007. This date will be used all along the paper when testing of significance increase of the adjusted correlations before and during the subprime crisis.

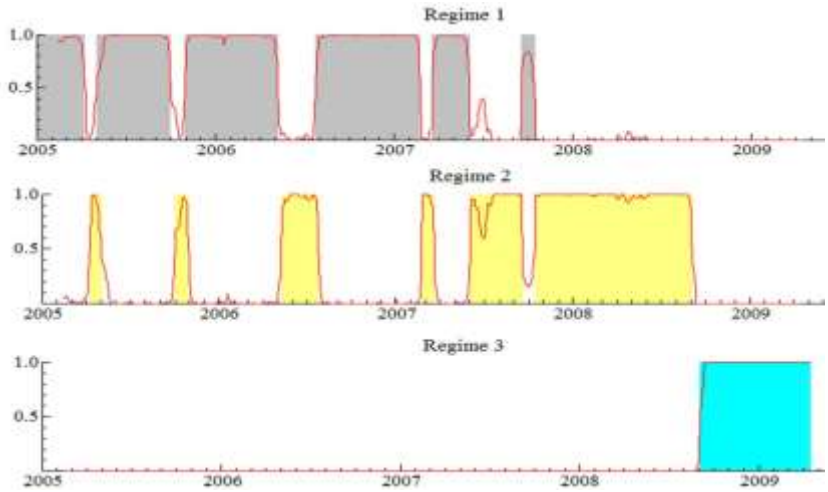

Fig. 9: Probabilities smoothing of a 3-states Markov Switching model

Correlation approach results:

In order to test for significant changes in correlation coefficients between the tranquil and turmoil periods we follow the same line as in Collins and Biekpe (2003), Corsetti *et al*. (2005) and Forbes and Rigobon (2002). As suggested by Forbes and Rigobon (2002) the estimation of cross-market correlation coefficients is biased because of heteroskedasticity in market returns. In other words, correlation coefficients tend to increase in crisis period due to the increase in volatility. To take into account heteroskedasticity, we adjust correlation coefficients as proposed by Forbes and Rigobon (2002).

It is evident that during the two periods there is co-movement between all stock markets of BRIC countries and the US market. The correlation shows that the link between BRIC countries market with US market has strengthened in the crisis period since July 13, 2007 as compared with the earlier period (February 2005-July 2007). The most important result is that the China market has an edge over the major other market such as Brazil and Russia in terms of the sharp increase in return correlation between the two periods, 2005-2007 and 2007-2009. Illustratively, it is evident that the increase in correlation between stock market in the China market and the US market during the second period as compared to the earlier period was 707 percent, the highest among other painting of regional market with the US market. Nevertheless, the stock return correlation of the China market with global market is lower than that of other countries markets with U.S markets. However, the results show that there was increase correlation coefficient during the U.S. subprime crisis. The null hypothesis of no increase in correlation is rejected by all cases during the U.S. subprime crisis.

Also, one can realize that correlation analysis is not enough to investigate financial contagion during the U.S. subprime crisis. In the next section, we discuss the econometric methodology that enables us to investigate financial contagion during the U.S. subprime crisis.

Table 4: results of the traditional and adjusted correlation tests

Country	Conditional (unadjusted) correlation Coefficients				Unconditional correlationcoefficients			(adjusted)
Country « zero » USA	Stable period	Crisis period	Student-test	contagion	Stable period	Crisis period	Student-test	contagion
	ρ_2	ρ_1			ρ_2^*	ρ_1^*		
Brazil	0.586	0.705	3.112	Y	0.205	0.259	1.806	N
Russia	0.202	0.243	5.802	Y	0.059	0.117	1.909	N
India	0.116	0.109	6.866	Y	0.034	0.098	2.147	Y
China	0.114	0.093	4.086	Y	0.033	0.071	1.239	N
Number of Obs.	630	458	-	-	630	458	-	-

The adjusted correlation coefficients suggest that there is no evidence of contagion for any BRIC market. In this case, we witness an interdependence phenomenon between the BRIC markets and the US market and not a pure contagion after the US sub-prime mortgages crises in 2007. Our results are similar to previous researches by Omri et Frikha (2011) and Hsien-Yi Lee (2012). This empirical finding is consistent with previous empirical based correlation approach studies suggesting that correlations of stock returns have been increased in recent periods as a result of increasing financial integration across national stock markets. This increasing of correlation leads to lower diversification benefits especially in the long-run horizons.

Nonlinear causality results:

To examine whether there is contagion or only interdependence from the USA to the BRIC countries, we start by performing the nonlinear causality tests to residuals extracted from the estimated VAR models for each couples of times series, (USA, Brazil), (USA, Russia), (USA, India) and (USA, China). Before applying these tests we need to determine the values of the lead length, *m*, the lag lengths, *Lx* and *Ly*, and the scale parameter, ϵ. Based on the empirical results of the Hiemstra and Jones (1993) Monte Carlo simulations, we set the parameter values of the nonlinear causality tests equals to $m = 1$, $Lx = 1$ to 8, $Ly = 1$ to 8 , and $\epsilon = 1.5\ \sigma$, where $\sigma = 1$.

Tables 5 and 6 report the results of nonlinear Granger causality tests for the tranquil and crises periods, respectively. From table 6, we report no significant nonlinear causality running from the USA to BRIC countries during tranquil countries except for India at only the fourth lag. This result is consistent with the fact that under the tranquil period, the five financial markets are characterized by low volatility and small correlation between stocks markets. As a consequence, it is expected that no significant nonlinear causality will be detected.

Table 5: Nonlinear causality results from USA to BRIC countries (Tranquil period)

	USA do not cause Brazil		USA do not cause Russia		USA do not cause India		USA do not cause China	
$L_x=L_y$	CS	TVAL	CS	TVAL	CS	TVAL	CS	TVAL
1	-0.669	-16.619	-0.468	-11.629	-0.618	-15.354	-0.610	-15.167
2	-0.465	-11.564	0.122	-3.029	-0.582	-14.449	-0.929	-23.096
3	-0.240	-5.981	-0.255	-6.349	-0.737	-18.315	-0.494	-12.284
4	-0.388	-9.645	-1.077	-26.757	0.092	-2.282	-0.053	-1.300
5	-0.272	-6.768	-0.245	-6.101	-0.029	-0.723	-0.225	-5.605
6	-0.045	-1.129	-0.136	-3.371	0.046	1.169	-0.288	-7.167
7	-0.473	-11.761	-0.286	-7.101	0.014	0.362	-0.308	-7.662
8	-0.566	-14.069	-0.646	-16.043	0.005	0.134	-0.356	-8.855

Note: CS and TVAL are, respectively, the difference between the two conditional probabilities and the Standardized test statistic. "Lx=Ly" denotes the number of lags in the residual series used in the test. **,* indicate, respectively, significance at the 1% and 5%, levels.

In contrast, during the crises period, we note a significant nonlinear causality relationship from the USA to Brazil, to India and to China countries. This finding suggests a contagion phenomenon from the USA to the three BRIC countries (Brazil, USA, and India). This contagion is more pronounced for the India country. For the Brazil and China countries the test of nonlinear causality is significant only in one lag, eight for the Brazil country and 4 for the China country.

Table 6: Nonlinear causality results from the USA to BRIC countries (Crises period)

	USA do not cause Brazil		USA do not cause Russia		USA do not cause India		USA do not cause China	
$L_x=L_y$	CS	TVAL	CS	TVAL	CS	TVAL	CS	TVAL
1	-0.539	-11.375	-0.268	-5.663	-0.533	-11.233	-0.548	-11.543
2	-0.447	-9.422	-0.248	-5.238	-0.533	-11.234	-0.758	-15.987
3	-0.302	-6.374	-0.163	-3.435	-0.878	-18.503	-3.089	-65.089
4	-0.176	-3.705	-0.075	-1.589	-1.210	-25.505	1.987	41.868**
5	-0.249	-5.258	-0.123	-2.600	-1.928	-40.629	-65.098	-1371.70
6	-0.0108	-0.228	-0.196	-4.145	1.046	22.038***	-0.289	-6.096
7	0.0643	1.357	-0.214	-4.517	0.312	6.583**	-0.432	-9.118
8	0.264	5.568**	-0.231	-4.879	-0.590	-12.438	-0.155	-3.276

Note: CS and TVAL are, respectively, the difference between the two conditional probabilities and the standardized test statistic. "Lx=Ly" denotes the number of lags in the residual series used in the test. **,* indicate, respectively, significance at the 1% and 5%, levels in the residual series used in the test. **,*indicate, respectively, %and5%,levels.

Implications and conclusion:

This paper investigated empirically whether any of the stock markets of BRICs region have been affected by the US subprime crisis. To this end daily indexes denominated in US dollars, for the Brazil, China, India, Russia, and USA countries have been used to examine whether contagion occurred across markets during the Global financial crises of 2007. The sample used covers the period from 10/02/2005 to 14/04/2009. To test for possible contagion versus interdependence, we use two econometrics approaches to test for changes in the relation between the USA stock market and other financial markets after the onset of the crisis : (1) the traditional adjusted correlation approach of Forbes and Rigobon (2002), and (2) the nonlinear causality approach of Hiemstra and Jones (1994).

The results obtained from the application of the two methods are not uniform. We found strong evidence for the presence of contagion phenomena from the USA stock market to the India stock market when we use Forbes and Rigobon approach as we found significant evidence of an increase in cross-market linkages between the tranquil and turmoil period. Using nonlinear causality method, we detect a contagion phenomenon for the Brazil and China countries. For the Russia country there is no evidence for the presence of contagion phenomena using all methods. In general, we can say that for most BRICs countries there is a menace of financial contagion which spread across markets as the subprime crisis developed. The results of this empirical analysis seem to support the operational advantages associated with definition of contagion proposed by Forbes and Rigobon (2001). In fact, the evidence of increased dependence between countries before and during crisis period should be prudently considered by portfolio managers as it suggests that a simple strategy of geographical diversification may not all the time be successful. The results provide a significant implication for the international investor and portfolio managers, who all are involved in reducing and managing their financial risk exposure. Moreover, as the results shown the benefits from international diversification depend from the country of BRIC region. Former researcher papers demonstrate that a negative shock to an emerging country can increase the relation between stock returns across countries, confusing investors' ability to differentiate their investments. From policymakers' perspective, this study provides important information about the directions for possible measures to take in order to protect emerging markets from contagion during future crises. The challenge for policymakers is to manage the process as to take full advantage of the opportunities, while minimizing the risks. However not all conditions are to be met before governments liberalize the financial

sector, countries should guarantee that the financial system is prepared to manage with foreign capital flows and external shocks. More complete policies for risk management are needed to build solid economies, in particular in terms of directive and administration of the financial system. The increasing integration of countries gives governments less policy instruments to manage the shock, so there is a crucial need for international financial policy coordination.

REFERENCES

Aloui, R., M.S.B. Aïssa and D.K. Nguyen, 2011. Global financial crisis, extreme interdependences, and contagion effects: The role of economic structure? Journal of Banking & Finance, 35(1): 130-141.

Angkinand, A., E.M. Chiu and T.D. Willett, 2009. Testing the unstable middle and two corners hypotheses about exchange rate regimes. Open Economies Review, 20(1): 61-83.

Antonakakis, N., I. Chatziantoniou and G. Filis, 2013. Dynamic co-movements of stock market returns, implied volatility and policy uncertainty. Economics Letters, 120(1): 87-92.

Baek, E.G. and W.A. Brock, 1992. A nonparametric test for independence of a multivariate time series. Statistica Sinica, pp; 137-156.

Baig, T. and I. Goldfajn, 1999. Financial market contagion in the Asian crisis. IMF Staff Papers, 46(2): 167-195.

Bekaert, G. and C.R. Harvey, 1997. Emerging equity market volatility. Journal of Financial Economics, 43(1): 29-77.

Beltratti, A., C. Morana and others, International shocks and national house prices, 2008. ICER-International Centre for Economic Research.

Bertero, E. and C. Mayer, 1990. Structure and performance: the Global interdependence of stock markets around the crash of October 1987∗. European Economic Review, 34(6): 1155-1180.

Billio, M. and L. Pelizzon, 2003. Volatility and shocks spillover before and after EMU in European stock markets. Journal of Multinational Financial Management, 13(4): 323-340.

Bonfiglioli, A. and C.A. Favero, 2005. Explaining co-movements between stock markets: The case of US and Germany. Journal of International Money and Finance, 24(8): 1299-1316.

Boyer, B.H., T. Kumagai and K. Yuan, 2006. How do crises spread? Evidence from accessible and inaccessible stock indices. The Journal of Finance, 61(2): 957-1003.

Caillault, C. and D. Guegan, 2005. Empirical estimation of tail dependence using copulas: application to Asian markets. Quantitative Finance, 5(5): 489-501.

Canarella, G. and S.K. Pollard, 2007. A switching ARCH (SWARCH) model of stock market volatility: some evidence from Latin America. International Review of Economics, 54(4): 445-462.

Calvo, S.G. and C.M. Reinhart, 1996. Capital flows to Latin America: is there evidence of contagion effects?

Celık, S., 2012. The more contagion effect on emerging markets: The evidence of DCC-GARCH model. Economic Modelling, 29(5): 1946-1959.

Celikkol, H., S. Akkoc and Y.D. Akarim, 2010. The Impact of bankruptcy of Lehman Brothers on the volatility structure of ISE-100 price index.

Chiang, T.C., B.N. Jeon and H. Li, 2007. Dynamic correlation analysis of financial contagion: Evidence from Asian markets. Journal of International Money and Finance, 26(7): 1206-1228.

Corsetti, G., M. Pericoli and M. Sbracia, 2005. "Some contagion, some interdependence": More pitfalls in tests of financial contagion. Journal of International Money and Finance, 24(8): 1177-1199.

Corsetti, G., L. Dedola and S. Leduc, 2005. DSGE models of high exchange-rate volatility and low pass-through.

Vaz de Melo Mendes, B., 2005. Asymmetric extreme interdependence in emerging equity markets. Applied Stochastic Models in Business and Industry, 21(6): 483-498.

Diamandis, P.F., 2008. Financial liberalization and changes in the dynamic behaviour of emerging market volatility: Evidence from four Latin American equity markets. Research in International Business and Finance, 22(3): 362-377.

Diebold, F.X. and K. Yilmaz, 2009. Measuring financial asset return and volatility spillovers, with application to global equity markets. The Economic Journal, 119(534): 158-171.

Edwards, S. and R. Susmel, 2001. Volatility dependence and contagion in emerging equity markets. Journal of Development Economics, 66(2): 505-532.

Engle, R., 2002. Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. Journal of Business & Economic Statistics, 20(3): 339-350.

Fidrmuc, J. and I. Korhonen, 2010. The impact of the global financial crisis on business cycles in Asian emerging economies. Journal of Asian Economics, 21(3): 293-303.

Forbes, K.J. and R. Rigobon, 2002. No contagion, only interdependence: measuring stock market comovements. The Journal of Finance, 57(5): 2223-2261.

Gagnon, L. and G.A. Karolyi, 2006. Price and volatility transmission across borders. Financial Markets, Institutions & Instruments, 15(3): 107-158.

Gelos, R.G. and R. Sahay, 2001. Financial market spillovers in transition economies. Economics of Transition, 9(1): 53-86.

Gilmore, C.K., S.E. McCarthy and E.S. Spelke, 2007. Symbolic arithmetic knowledge without instruction. Nature, 447(7144): 589-591.

González-Hermosillo, B., 2008. Investors risk appetite and global financial market conditions.

Gómez-Puig, M. and S. Sosvilla-Rivero, 2013. Granger-causality in peripheral EMU public debt markets: A dynamic approach. Journal of Banking & Finance, 37(11): 4627-4649.

Hamao, Y., R.W. Masulis and V. Ng, 1990. Correlations in price changes and volatility across international stock markets. Review of Financial Studies, 3(2): 281-307.

Hamilton, J.D. and R. Susmel, 1994. Autoregressive conditional heteroskedasticity and changes in regime. Journal of Econometrics, 64(1): 307-333.

Hsieh, D.A., 1991. Chaos and nonlinear dynamics: application to financial markets. The Journal of Finance, 46(5): 1839-1877.

Hsieh, D.A., 1989. Testing for nonlinear dependence in daily foreign exchange rates. Journal of Business, 339-368.

Khalid, A.M. and M. Kawai, 2003. Was financial market contagion the source of economic crisis in Asia?: Evidence using a multivariate VAR model. Journal of Asian Economics, 14(1): 131-156.

Khallouli, W. and R. Sandretto, 2012. Testing for" contagion" of the subprime crisis on the Middle East and North African stock markets: A Markov Switching EGARCH approach. Journal of Economic Integration, pp: 134-166.

Khan, S. and K.W.K. Park, 2009. Contagion in the stock markets: The Asian financial crisis revisited. Journal of Asian Economics, 20(5): 561-569.

Khan, S., F. Islam and S. Ahmed, 2005. The Asian crisis: an economic analysis of the causes. The Journal of Developing Areas, 39(1): 169-190.

Karolyi, G.A. and R.M. Stulz, 1996. Why do markets move together? An investigation of US-Japan stock return comovements. The Journal of Finance, 51(3): 951-986.

Kenourgios, D., A. Samitas and N. Paltalidis, 2011. Financial crises and stock market contagion in a multivariate time-varying asymmetric framework. Journal of International Financial Markets, Institutions and Money, 21(1): 92-106.

King, M.A. and S. Wadhwani, 1990. Transmission of volatility between stock markets. Review of Financial Studies, 3(1): 5-33.

Lee, S.B. and K.J. Kim, 1993. Does the October 1987 crash strengthen the co-movements among national stock markets? Review of Financial Economics, 3(1): 89.

Longin, F. and B. Solnik, 1995. Is the correlation in international equity returns constant: 1960–1990? Journal of International Money and Finance, 14(1): 3-26.

Longin, F. and B. Solnik, 2001. Extreme correlation of international equity markets. The Journal of Finance, 56(2): 649-676.

Longstaff, F.A., 2010. The subprime credit crisis and contagion in financial markets. Journal of Financial Economics, 97(3): 436-450.

Loretan, M. and W.B. English, 2000. Evaluating correlation breakdowns during periods of market volatility.

Yılmaz, M., 2015. Auctioning a discrete public good under incomplete information. Theory and Decision, 78(3): 471-500.

Masih, A.M. and R. Masih, 1999. Are Asian stock market fluctuations due mainly to intra-regional contagion effects? Evidence based on Asian emerging stock markets. Pacific-Basin Finance Journal, 7(3): 251-282.

Naoui, K., N. Liouane and S. Brahim, 2010. A dynamic conditional correlation analysis of financial contagion: The case of the subprime credit crisis. International Journal of Economics and Finance, 2(3): 85-96.

Papavassiliou, V.G., 2014. Cross-asset contagion in times of stress. Journal of Economics and Business, 76: 133–139.

Patton, A.J., 2006. Modelling asymmetric exchange rate dependence. International Economic Review, 47(2): 527-556.

Pesaran, M.H., D. Pettenuzzo and A. Timmermann, 2006. Forecasting time series subject to multiple structural breaks. The Review of Economic Studies, 73(4): 1057-1084.

Omri, A. and M. Frikha, 2011. No Contagion, Only Interdependence During the US Sub-Primes Crisis. Transition Studies Review, 18(2): 286-298.

Ramlall, I., 2010. Has the US subprime crisis accentuated volatility clustering and leverage effects in major international stock markets? International Research Journal of Finance and Economics, 39(13): 157-185.

Reinhart, C. and G. Kaminsky, 2000. Crisis financieras en Asia y Latinoamerica: ahora y entonces.

Rigobon, R., 2003. On the measurement of the international propagation of shocks: is the transmission stable? Journal of International Economics, 61(2): 261-283.

Samitas, A. and I. Tsakalos, 2013. How can a small country affect the European economy? The Greek contagion phenomenon. Journal of International Financial Markets, Institutions and Money, 25: 18-32.

Yiu, M.S., W.-Y. Alex Ho and D.F. Choi, 2010. Dynamic correlation analysis of financial contagion in Asian markets in global financial turmoil. Applied Financial Economics, 20(4): 345-354.