Lead-Lag Effect in the Stock Market of BRICS

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Abstract: Recent performance of Brazil's stock market contributed to attracting investments from various parts of the globe. This study aims to examine the lead-lag effect between the stock market of the BRICs, from March 2004 until March 2013, using the methodology proposed by Shih Chen and Hsiao (2008). Among the results the research emphasizes, we analyzed that the Brazilian market is leading others stock exchange in periods before and after the financial crisis, which the magnitude of the effect took about two days to be dissipated.

Keywords: Lead-lag effect, impulse response analysis, BRICs, Brazil

1. Introduction

Due to globalization of international financial markets there was greater interaction between them, in which the process of reconfiguration of the global economic scenario, headed by advances in information technology and telecommunications, has strengthened the relationship between the different markets, allowing the turmoil in the economies of developed countries more severely affecting the domestic market. One consequence of this phenomenon is that assets traded in different markets will have similar risks. In other words, if the capital market is integrated, the financial assets traded in each distinct market should have the same risk and consequently the same expected return. Thus, investors could use this correlation between the domestic and international market to take advantage of the carry trade operations and improve their distribution of risk (Oliveira, 2008; Shih, Hsiao, Chen; 2008).

For the Brazilian case, the changes in the economic sphere area result of trade and financial liberalization, in conjunction with the context of economic stability after the *Plano Real*, which improved country's reputation on the world stage and the notoriety of Brazil in the global scenario. Alves (2008) emphasizes that the increase of the Brazil's investment grade by Standard & Poor's (S&P) in April 2008 provided a significant inflow of capital in the country. In addition, the institutional changes of the Brazilian stock exchange have expanded the importance of this country in international finance. On March 26th, 2008, the Mercantile and Futures Exchange (BM&F) and the São Paulo Stock Exchange (BOVESPA) merged, resulting in the BM&FBOVESPA. According to its idealizers the creation of the "New Exchange", should reduces transaction costs and jointly with the structured organizational environment and existing technological bases allow this stock exchange become a liquidity center for Latin America (BVMF, 2013).

According to the Future Industry Association (FIA), the BM & FBovespa increased by 433.77% in the amount of contracts, from 304.21 to 1,635.96 million of contracts traded between 2003 and 2012. In 2012 the BM&F segment traded 704.09 million contracts and the Bovespa part traded 931.87 million contracts

(Acworth, 2013).That being said, considering the lowest default risk, the high interest rates that promote the carry trade operations, along with the recent dynamism of the economy and the performance of the Brazilian stock market, Brazil became a probable destination for international investments. Because of the increasing participation of developing countries in international financial markets, especially the BRIC ones (O'NEILL, 2001), this study aims to analyze the lead-lag effect between the equity markets of Brazil, Russia, India and China. For this, the study uses the methodology proposed by Shih, Hsiao and Chen (2008), calculating the lead-lag effect for the markets of Brazil (Bovespa index or Ibovespa), Russia (RTS index), India (BSE Sensex index) and China (SSE Composite index) from April 1st 2004 to March 30th 2013.

The analysis of the countries that compose the BRIC is relevant to the extent that, even with the drop in derivative contracts traded around the world in 2012, the stock exchanges of those countries has generally shown growth in the volume of contracts, being listed in "Top 30 Derivatives Exchanges" of FIA Annual Volume Survey (FIA, 2013). As a result of the systemic crisis that assumed a global character after the collapse of Lehman Brothers on September 15th, 2008 (Freitas, 2009) this paper assesses if there were any changes in the lead-lag effect before (2004-2008) and after (2008-2013) the financial crisis.

2. Literature review

The lead-lag effect, according to Nakamura (2009), is perceived when there is a relationship between the price movements of two distinct markets, whereby one of them leads and the other follows with some lag time. When this effect is identified, there is a rupture of the Efficient Market Hypothesis (EMH). For Jiang, Fung and Cheng (2001, p.65), lead-lag is defined as "the phenomenon that reflects the situation when two prices move in sequence." According to Oliveira (2008), the EMH hypothesis developed by Fama (1970)[1] states that stock prices behave like a random walk, not being subject to forecasting and arbitrage transactions. Lemos and Costa Junior (1995) postulate that EMH hypothesis requires the non-occurrence of any ex post irregularities in the observed returns, i.e. the absence of standards of market behavior resulting in abnormal returns.

If the EMH hypothesis fails to explain the relationship between two markets, Oliveira (2008) claims that a more developed market may precede the other markets, and it can predict, with a reasonable level of confidence, the movement of lead market prices, creating opportunities of arbitrage that lead to abnormal returns. Nakamura (2009) adds that if there are any barriers or incomplete flow of information, such factors may cause lags in asset returns.

Since the lead-lag effect captures the relationship between two markets, the definition of those markets provides a wide applicability of this methodology. Miller (1980) used the lead-lag effect to verify that the wholesale price leads the producer price of pork meat in the United States. With regard to stock market, the lead-lag effect was used in different ways, such as the analysis of the relationship between the spot and future markets, as proposed by Herbest, McCormack and West (1987) for the S&P 500, with intraday data. Subsequently, Tse (1995) examined the lead-lag relationship between the Nikkei spot and futures contract about Nikkei index and found that lagged changes in futures price cause adjustments in the spot price in the short run, but the reverse is not true. On its turn, Brooks, Rew and Ritson (2001) studied the London

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[1] Fama, E. F. Efficient capital markets: a review of empirical work, Journal of Finance, 383-417, 1970.

market by the FTSE 100 index, and Mendez Suarez (2008) analyzed the autocorrelation, lead-lag relationship to and dependence on the volatility IBEX 35 index in spot and future market using daily prices of one and five minutes throughout the year 2003[2].

Among other applications, Daigler (1990) emphasizes the analysis of the potential opportunities for arbitration proposed by who used five-minute intervals for the S&P 500, MMI index and contracts of the NYSE; analysis of the relationship between stock returns and trading volume, proposed by Saatcioglu and Starks (1998) for six countries in Latin America.

It is worth highlighting the study of co-movements and causality to markets in the United States, United Kingdom and six Asian markets conducted by Meric et al. (2008), five years before and five years after September 11th, 2001. The authors used the technique of principal component analysis to determine if the standards of co-movements of the markets of USA, UK, Australia, China, Russia, India, Japan and South Korea have changed with the analyzed periods. The conclusions of the study indicate that the principal component analysis is a useful technique to study contemporary co-movements of stock market, and Granger causality is a useful technique to study the lead-lag linkages between stock markets.

Despite different objectives, the similarity in these works is the use of indices of stock exchanges. For Nakamura (2009), the use of these indices is justified as it represents the average performance of the price of a stock portfolio, that is, indicates reliably the behavior of stocks traded in a particular stock exchange. In short, one of the worries of researchers over the past two decades was to evaluate the existence of lead-lag effect comparing the stock indices of different markets. In this context, it is worth highlighting the pioneering work of Malliaris and Urrutia (1992) that examined the lead-lag effect for six major stock market indexes, comparing these indices between the period before and after the crisis of 1987 submitted significant changes between those periods. On the other hand, Shih Hsiao and Chen (2008) explored the relationship between the indices of the markets of China, Japan and the United States and the results show that there is not a co-integration relationship between these markets.

For the Brazilian case, Gaio and Rolim (2007) measured the impact of the change in the main indices of world stock exchanges in the Bovespa index, presenting evidence that the behavior of the return series of the international exchange stock influences the Brazilian stock market returns. This can be explained by the existence of foreign speculators trading on the Bovespa, which would lead to similar fluctuations. Oliveira (2008)[3] studied the co-movements of the Dow Jones and Bovespa indexes and identified the existence of lead-lag effect between the Brazilian and the U.S. stock market in the period July 2006 to September 2007, using data with intraday frequency of one minute. The author concludes that the realization of arbitration based on the lead-lag effect is not economically viable as a consequence of the transaction costs. For its part, Nakamura (2009) shows the existence of lead-lag between the Brazilian stock market and American Depositary Receipts market (ADRs) traded on the New York Stock Exchange.

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[2] Among the contributions of this study, it is found that as increased the frequency of the data series have increased autocorrelation and Heterocedasticity indicating a lower randomness.

[3] Among the contributions from Oliveira (2008), we highlight the identification of co-integration between the two markets by testing Engle and Granger and Johansen, as well as the existence of bidirectional causality by means of the Granger causality test.

Pena, Guelman and Rabello (2010) analyzed the relationship of the Dow Jones index and the Nikkei-225 index with the Bovespa index, estimating a log-log model by Ordinary Least Squares (OLS), with daily data of the variation of the three indices in the period of January 2006 to May 2008. Among the results, the authors identified contemporary relations between the Dow Jones and Bovespa indexes. The authors also indicated the possibility of lag in the relationship between the Ibovespa and Nikkei-225 indexes due to the different time zones in which those stock exchanges perform their operations, and also the existence of information that affect the market in the period in which trading floor is not open for business.

In this way, the present study differs from other studies on the subject, whereby the focus is centered on the analysis of indexes of stock exchanges in emerging countries, especially the members of BRIC. Since April 14th, 2011, on the occasion of the 3rd Summit of the Cluster of the representatives of these countries that occurred in Sanya, Haynan Province, in China, South Africa has been integrated in this group, adding the letter S to the acronym BRICS, however due the unavailability of data about Johanensburgo Stock Exchange index (JSE) for the entire period of analysis, this country was not included in the scope of this study. Furthermore, this study also sought to determine if the international financial crisis had an effect on the relationship between the stock exchanges of these countries.

3. Methodology

3.1. Data scope and source

In this study, we collected data with daily frequency of stock market indices in Brazil, Russia, India and China, taken from March 1st, 2004 until March 30th, 2012.Khan et al. (2010) submits that the results of the daily data are more accurate and are more able to capture the dynamic lead-lag between different indicators of the stock market. The sampling period in this study was based on the analysis of the effects of the outbreak of the international financial crisis, the starting point being about four years before and after the bankruptcy of Lehmans Brothers Bank. During this period, the Bovespa index was collected at BM & FBovespa, the RTS1 index in Russia Trading System Stock Exchange, SSE Composite Index of Shanghai Stock Exchange and the BSE index of the Bombay Stock Exchange (CMA, 2013).Then the series were equalized, considering only price references for the periods in which the two exchanges were operating simultaneously, removing missing values as local holidays, according proposed by Oliveira and Medeiros (2009), thereby the period analyzed includes 2,010 observations.

In short, the study aims to analyze the interaction between the stock markets of the member countries of the BRIC. For this, the sample is divided into two sub-periods, 2004-2008 and 2008-2013. In a first moment, the sub-period from March 2004 until September 2008, we intend to analyze the lead-lag relationship in the period preceding the global financial crisis. In a second stage, the same analysis will be made for the period from September 2008 until March 2013, with the aim of evaluating the effects of the global financial crisis and its recent developments. To perform the unit root tests, cointegration and Granger causality and to estimate the VAR model, the study used the software Stata 11.

3.2. Empirical specification

This section presents the methodological procedures used to achieve their search objectives. First, in an empirical time series analysis, such as the analysis of stock exchange indexes in financial markets, when

applying the classic model of linear regression it is assumed that the series are stationary, that is it is assumed that the indexes analyzed are subject to the random walk process. In this way, a data series is said to be stationary if its mean and variance are constant (non-changing) over time and the value of covariance between two time periods depends only on the distance or lag between the two time periods and not on the actual time at which the covariance is computed. In this research, to determine whether the time series are stationary, augmented Dickey–Fuller (ADF proposed in 1979, 1981) unit root test is performed. In this sense, the spurious regression problem has been solved with the specification of the ADF test on three different types. The model with no drift term and no trend term can be defined as follows:

$$\Delta Y_t = \gamma Y_{t-1} + \sum_{i=1}^{m} \delta_t Y_{t-1} + \varepsilon_t \qquad (1)$$

Random walk mode with drift term but without trend term, as shown below

$$\Delta Y_t = \alpha_0 + \gamma Y_{t-1} + \sum_{i=1}^{m} \delta_t Y_{t-1} + \varepsilon_t \qquad (2)$$

And, Random walk mode with drift term and trend term is specified as

$$\Delta Y_t = \alpha_0 + \beta T + \gamma Y_{t-1} + \sum_{i=1}^{m} \delta_t Y_{t-1} + \varepsilon_t \qquad (3)$$

Where: $\Delta Y = Y_t - Y_{t-1}$; α_0 was intercept term, T was time trend term and ε_t was a white noise, i.e., a random disturbance with zero mean and constant variance, or $\varepsilon_t \sim iid \quad N(0, \sigma^2)$. Thus, we can use this model to test whether a series is stationary or not by null hypothesis $H_0 : \gamma = 0$. When we failed to reject null hypothesis, this indicated these series have unit root, being non-constant series; if we rejected null hypothesis, then it would indicate the series had no unit root, it was a constant series.

If the series are stationary, we can use the Granger causality test and the estimation of VAR models to study the relationship between economic variables. The models of Vector Autoregressive (VAR) developed by Sims (1980) are commonly used in a group of variables to examine linear relationships between each variable and the lagged values of itself and all other variables being considered a dynamic model in which all economic variables are treated as endogenous. In this context, the VAR model can be defined in matrix formas:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \cdot \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \qquad (4)$$

Where $\varepsilon_{1t} \sim I(0)$ and $\varepsilon_{1t} \sim I(0)$ it indicates that y_t and x_t follow a VAR (1) process. So, for n variables the VAR process can be rewritten in the reduced form, as follows:

$$y_t = \Theta_0 + \Theta y_{t-1} + ... + \Theta_p y_{t-p} + \varepsilon_t \qquad (5)$$

Where each Θ_j is a matrix of parameters $k \times k$ and ε_t is ak-dimensional vector terms of white noise, with $Cov(\varepsilon_{it}, \varepsilon_{st}) = 0$ for $i \neq s$, it indicates y_t follows a VAR (p) process. Thus, in VAR, each variable can be expressed as a linear combination of their values and all lagged variables. This model seeks to estimate the response of each variable to unanticipated shocks in the others and the importance of each variable in

terms of the predictive behavior of the other variables. Finally, the procedure is the application of the concept of co-integration to verify the existence of a long-run equilibrium among the variables.

4. Empirical results

For performing the unit root tests was necessary to determine the number of lags by Akaike Information Criteria and Schwartz Criteria. The next step is to determine the order of integration by means of the unit root test. For this purpose, the test Augmented Dickey-Fuller (ADF) [Dickey and Fuller (1979)] was performed according to the procedures described by Enders (2010) and Rao (1994).

Table 1. ADF Unit root result of Brasil, Russia, India and China stock indices

t	Variable	Lag^a	Augmented Dickey-Fuller (ADF)[1]						Integration order
			τ_τ	φ_3	φ_2	τ_μ	φ_1	τ	
Mar. 01, 2004 to Sept.15, 2008	lbrasil[2]	0	-1.95^{ns}	2.18^{ns}	2.07^{ns}	-1.16^{ns}	1.58^{ns}	1.31^{ns}	
	lchina[2]	0	-0.50^{ns}	0.22^{ns}	0.18^{ns}	-0.65^{ns}	0.27^{ns}	0.29^{ns}	
	lrussia[2]	0	0.92^{ns}	1.72^{ns}	1.50^{ns}	-1.18^{ns}	1.22^{ns}	0.94^{ns}	
	lindia[2]	0	-1.27^{ns}	1.12^{ns}	1.44^{ns}	-1.15^{ns}	1.69^{ns}	1.38^{ns}	
	∇ lbrasil[3]	0	-31.67**	501.65**	-	-	-	-	I(1)
	∇ lchina[3]	0	-32.75**	536.29**	-	-	-	-	I(1)
	∇ lrussia[3]	4	-20.99**	220.28**	-	-	-	-	I(1)
	∇ lindia[3]	0	-32.09**	514.72**	-	-	-	-	I(1)
Sept. 16, 2008 to Mar.30, 2013	lbrasil[2]	0	-1.92^{ns}	1.98^{ns}	1.33^{ns}	-1.96^{ns}	1.95^{ns}	0.18^{ns}	
	lchina[2]	0	-2.39^{ns}	3.64^{ns}	2.44^{ns}	-1.97^{ns}	1.98^{ns}	0.19^{ns}	
	lrussia[2]	1	-1.91^{ns}	1.86^{ns}	1.28^{ns}	-1.65^{ns}	1.42^{ns}	0.26^{ns}	
	lindia[2]	0	-1.67^{ns}	1.40^{ns}	1.06^{ns}	-1.31^{ns}	1.04^{ns}	0.58^{ns}	
	∇ lbrasil[3]	0	-33.23**	552.00**	-	-	-	-	I(1)
	∇ lchina[3]	0	-30.65**	469.62**	-	-	-	-	I(1)
	∇ lrussia[3]	0	-28.89**	417.51**	-	-	-	-	I(1)
	∇ lindia[3]	0	-31.18**	486.16**	-	-	-	-	I(1)

Note: *, ** denote rejecting unit root null hypothesis at 5% and 1% significant level respectively, and ^{ns} result is not significant. [1] Critical values for τ_τ, τ_μ e τ are -3.447, 2.885 e 1.943 to significance at the 5%, -4.068, -3.485 e -2,582 to significance at the 1% respectively, whereas critical values of φ_3, φ_2 e φ_1 correspond 6.250, 4.680 e 4.710 to significance at the 5% and 8,270, 6.090 e 6.700 to significance at the 1%, as presented in Dickey and Fuller (1981). [2] Variable in level, [3] Variable in first difference.

The methodology used to perform the ADF test as described in Enders (2010) and Rao (1994) consists of performing a series of tests in order to identify the stationarity, without incurring statistical errors that can influence the results of the estimated model. Therefore, as seen in Table 1, the indices of stock markets of Brazil, China, Russia and India are stationary only in the first difference in the two periods. In this way those indices have mean, variance and covariance constant in time. In the following, it is necessary to check if the series used are cointegrated. The first step is to perform the Cointegration Test of Granger Test (1987) that consists of estimating an OLS model between two markets, get the estimated residuals and make the ADF unit root test. If the null hypothesis that the model residuals have a unit root is rejected, there hence is a long-term relationship between the variables.

It is worth mentioning that this paper estimated three models for each period analyzed, which produced a time series of estimated residuals for each model. These residues have been nominated by the order of OLS estimation of models that relate Brazilian stock exchange with stock market shares of China (Res1), Russia (Res2) and India (Res3), respectively.

Therefore, as verified in table 2, only the series Res1 and Res2 in the first period analyzed did not reject the null hypothesis of ADF unit root test, demonstrating that the Brazilian stock exchange did not have a long-term relationship with the stock exchanges of India and Russia until 2008; namely, the shares of companies traded in those stock exchanges participated in different market structures.

Table 2. ADF Unit root result for the residue of the models estimated by Ordinary Least Squares (OLS)

Variable	Lag^a	Time	Augmented Dickey-Fuller (ADF)[1]						Integration order
			τ_τ	φ_3	φ_2	τ_μ	φ_1	τ	
Res1[1]	1	1	-1.90^{ns}	1.88^{ns}	1.64^{ns}	-1.78^{ns}	2.17^{ns}	-1.78^{ns}	
Res2[1]	2	1	-2.06^{ns}	2.29^{ns}	1.65^{ns}	-1.81^{ns}	1.83^{ns}	-1.82^{ns}	
Res3[1]	1	1	-3.32^{ns}	5.52^{ns}	3.68^{ns}	-3.25*	-	-	I(0)
Res1[1]	1	2	-3.22^{ns}	5.19^{ns}	3.47^{ns}	-2.10^{ns}	2.22^{ns}	-2.101*	I(0)
Res2[1]	1	2	-3.09^{ns}	5.03^{ns}	3.36^{ns}	-2.69^{ns}	3.62^{ns}	-2.69**	I(0)
Res3[1]	5	2	-3.82*	7.60*	-	-	-	-	I(0)

Note: *, ** denote rejecting unit root null hypothesis at 5% and 1% significant level respectively, and ^{ns} result is not significant. [1] Critical values similar to table 1;[2] Variable in level; [3] Variable in first difference.[a] The lag value is determined by the Schwarz Criterion (SIC) and Akaike Information Criteria (AIC)

Accordingto Bichara and Camargos (2011) when BM&F and Bovespa merged in 2008 there was an increase in the integration of the Brazilian capital market with other countries. That merger originated the third largest stock exchange in the world by market value, as well as making the capital market in Brazil more efficient, structured and transparent with a higher level of liquidity. This merger also allowed the New Exchange to become an institution with technological, operational and financial power, offering new financial products and services, becoming a reference in Latin America. Those changes in the Brazilian stock exchange with the outbreak of the international financial crisis increased integration of financial markets around the world, and these changes help to explain the long-term relationship between the respective stock market indices in China and Russia observed after 2008. However, this paper will only make a short-term analysis by means of the VAR model, in order to verify the dynamics of unexpected shocks among the variables, using the impulse response function and variance decomposition, contributing to analysis of variance of the error in the model of endogenous variable.

For this purpose, we performed tests of serial autocorrelation, heteroscedasticity, normality and characteristic polynomial, in order to estimate a robust VAR model that does not show spurious results, which would result in inconsistent conclusions to the actual situation in the economy. In this context, in the estimation of the model with the appropriate number of lags, auto-correlated residues are not identified considering the results of Lagrange Multiplier test at5% level of significance. Regarding the diagnosis of heteroscedasticity, according to the White test, the residuals are homo scedasticat a significance level of 5%.However, the null hypothesis of Jarque-Bera tests for normality of observations and regression disturbances was rejected. Note that this problem tends to be minimized based on the Central Limit Theorem, which postulates that whatever the distribution of the variable of interest for large samples, the

mean of the sample will tend to a normal distribution as the sample size grows. Moreover, the characteristic polynomial of the test showed that all the roots of the model are included within the unit circle, which the VAR is stable. After validating the assumptions of robustness of the VAR model is estimated impulse response function. The impulse response function is used to evaluate how a shock not expected in a particular variable is passed to the other variables in the VAR model. For such, all the shocks experienced by the model were previously orthogonalized using the Cholesky decomposition. (Figure 1).

As shown in figure 1, in both periods analyzed note that an unexpected shock in the index of the Brazilian stock exchange has a positive effect in Chinese stock index, as well as an unexpected shock in Chinese stock index also causes a positive in the Brazilian market but at a lower intensity. Based on these results it appears that the Brazilian stock market leads the Chinese market. So, economic agents, when buying or selling shares of Chinese companies, use information from Brazilian companies in their process of formation of expectations. Note that the mean time for the dispersion effect takes around two days, demonstrating the high dynamics of the capital markets in those two countries in the analyzed periods. However, to have more conceptual effects between those markets, it is necessary to check the variance decomposition of the two estimated models.

Figure 1. Impulse response function for the VAR model for the indices of stock exchanges in Brazil and China
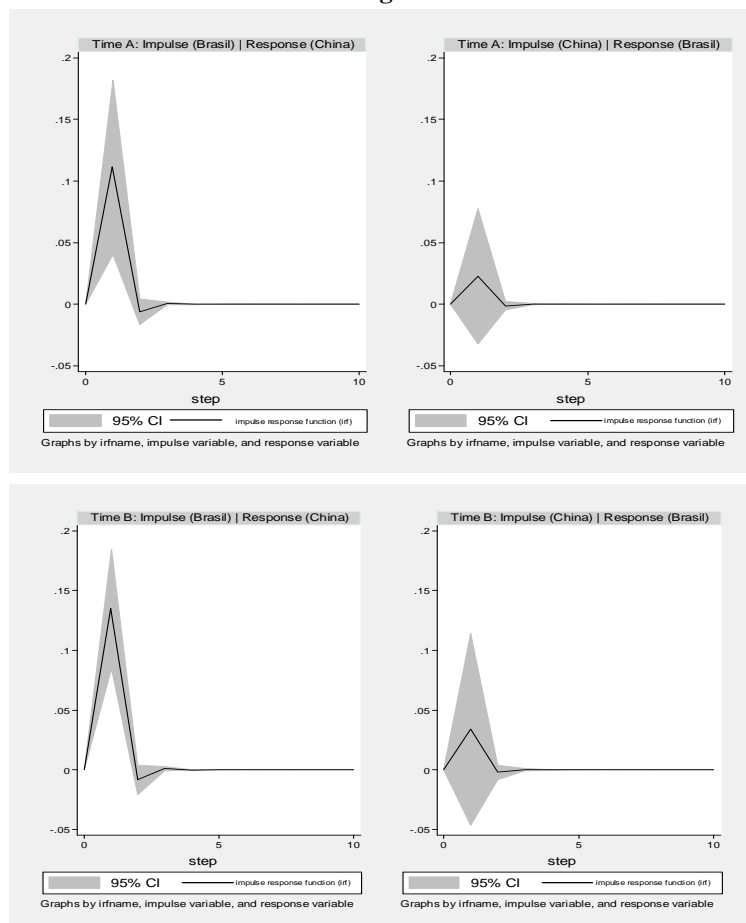
Note: Time A: Corresponds to the first reporting period (Mar. 01, 2004 to Sept.15, 2008); Time B: Corresponds to the second reporting period (Sept. 16, 2008 to Mar.30, 2013).

The decomposition analysis of variance (table 3) shows that only 0.1% of the variance of the index of the Brazilian stock exchange is explained by the Chinese Stock Market, in both periods analyzed. However, when analyzing the variance on the Chinese market, we note that the representativeness of the Brazilian stock market is higher (2.5%), and tends to increase in the second period (9.0%). This result indicates that the Brazilian market leads the Chinese market, demonstrating that it has become more significant in recent years due to recent structural changes in the capital markets in Brazil. Moreover, it is necessary to verify whether the above effects are found in the Russian capital market.

Table 3. Variance decomposition of forecast errors in the indices of stock exchanges in Brazil and China

Var.	days	lbrasil	lchina	Var.	lbrasil	lchina
First period: Mar. 01, 2004 to Sept.15, 2008						
lbrasil	1	100.0%	0.0%	lchina	1.6%	98.4%
	2	99.9%	0.1%		2.5%	97.5%
	3	99.9%	0.1%		2.5%	97.5%
	10	99.9%	0.1%		2.5%	97.5%
Second period: Sept. 16, 2008 to Mar.30, 2013						
lbrasil	1	100.0%	0.0%	lchina	6.4%	93.6%
	2	99.9%	0.1%		9.0%	91.0%
	3	99.9%	0.1%		9.0%	91.0%
	10	99.9%	0.1%		9.0%	91.0%

As shown in figure 2, note that economic agents that trade shares of Russian companies which are part of the index examination (RTS1) use information from Brazilian companies in their process of formation of expectations, as the unexpected shocks market Brazilian equity are transferred to the Russian market in about two days. Based on these results it appears that the Brazilian stock market leads the Russia stock market, according to the indices used in this study.

Regarding the decomposition analysis of the variance of the estimated models, it appears that variations of the stock market of Russia have a small parcel of explanation of the variations of the Brazilian market, getting an average of 0.5% in both periods. However, when analyzing the variance of Russian stock exchange, note that the Brazilian explains approximately 19.6% in the first period and 37% in the second period.

Figure 2. Impulse response function for the VAR model for the indices of stock exchanges in Brazil and Russia

Note: Time A: Corresponds to the second reporting period (Mar. 1, 2004 to Sept.15, 2008); Time B: Corresponds to the second reporting period (Sept. 16, 2008 to Mar.30, 2013).
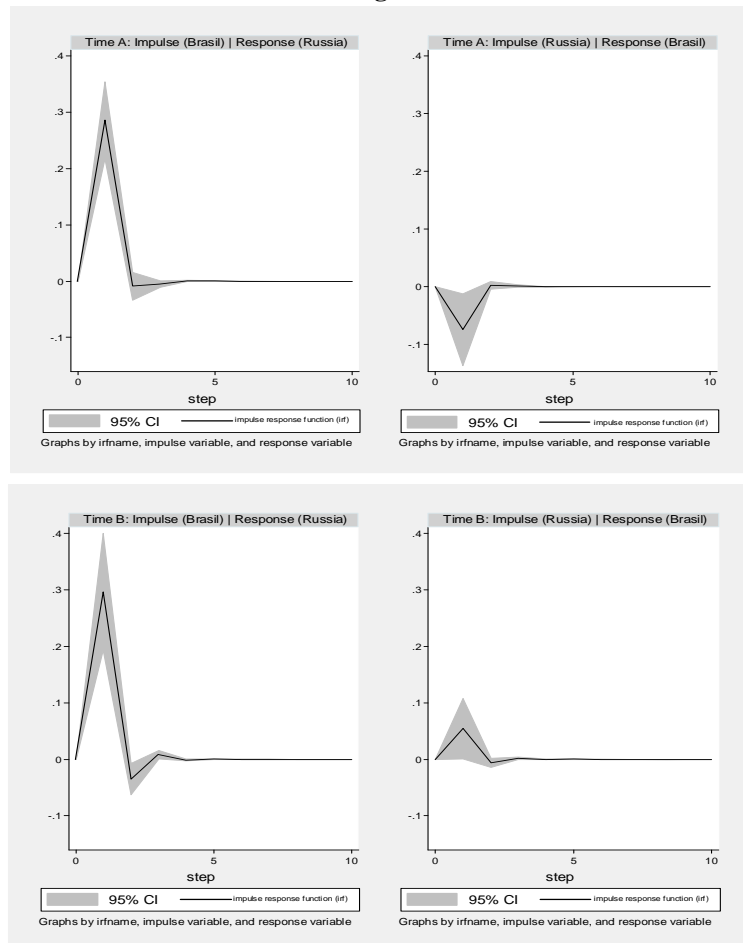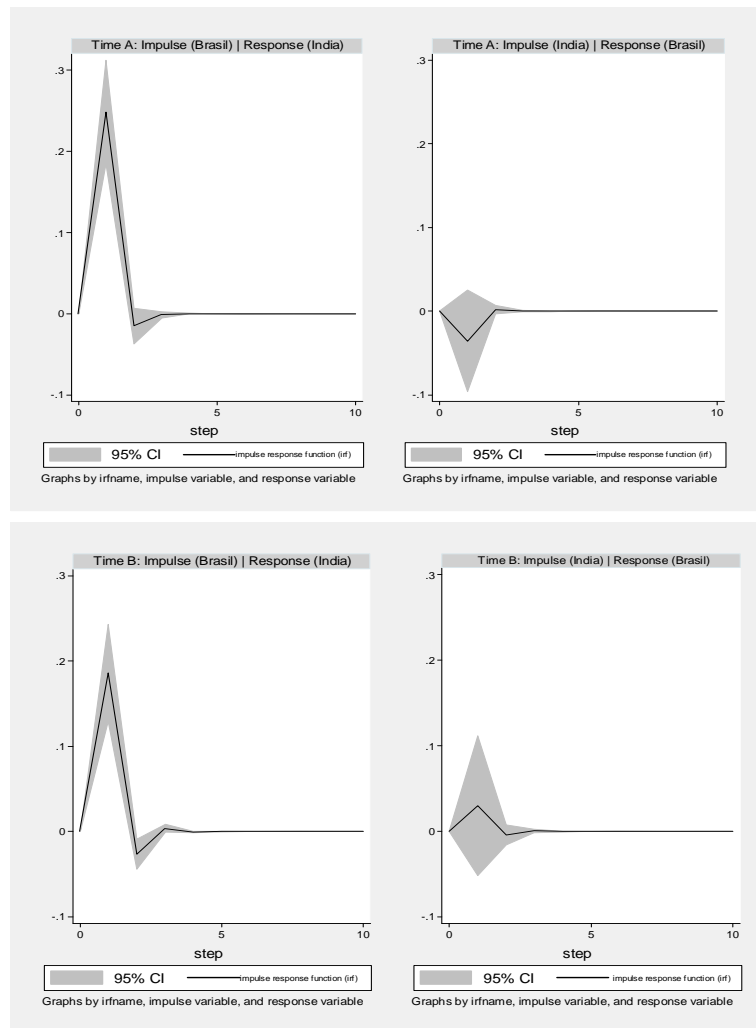
Table 4. Variance decomposition of forecast errors in the indices of stock exchanges in Brazil and Russia

Var.	Days	lbrasil	lchina	Var.	lbrasil	lchina
First period: Mar. 01, 2004 to Sept.15, 2008						
lbrasil	1	100.0%	0.0%	lrussia	14.3%	85.7%
	2	99.5%	0.5%		19.6%	80.4%
	3	99.5%	0.5%		19.6%	80.4%
	10	99.5%	0.5%		19.6%	80.4%
Second period: Sept. 16, 2008 to Mar.30, 2013						
lbrasil	1	100.0%	0.0%	lrussia	35.2%	64.8%
	2	99.6%	0.4%		37.6%	62.4%
	3	99.6%	0.4%		37.6%	62.4%
	10	99.6%	0.4%		37.6%	62.4%

Finally, to perform the analysis of the Brazilian and Indian stock markets obtains results similar to the results observed for China and Russia. The Brazilian stock index has a leading effect on the Indian stock exchange, with any unexpected movements in the Brazilian market will be arbitrated by the economic agents involved in the financial market, positively affecting Indian stock exchange. However, it is necessary to verify the magnitude of that effect, and if it persists in analyzed period.

Therefore, as mentioned above the Brazilian stock exchange has an effect on the lead Indian stock exchange, causing approximately 9.7% of the variance is explained by the Indian stock exchange Brazilian stock market in the first period. This effect becomes approximately 24% in the second period, reinforcing the hypothesis that structural changes in the Brazilian capital markets were important for the consolidation of the Brazilian stock exchange in the BRICS, and in the global context. Those results confirm the Brazilian capital market lead on the BRICS.

Figure 3. Impulse response function for the VAR model for the indices of stock exchanges in Brazil and India

Table 5. Variance decomposition of forecast errors in the indices of stock exchanges in Brazil and India

Var.	days	*lbrasil*	*lchina*	Var.	*lbrasil*	*lchina*
		First period: Mar. 01, 2004 to Sept.15, 2008				
lbrasil	1	100.0%	0.0%	lindia	4.8%	95.2%
	2	99.9%	0.1%		9.7%	90.3%
	3	99.9%	0.1%		9.7%	90.3%
	10	99.9%	0.1%		9.7%	90.3%
		Second period: Sept. 16, 2008 to Mar.30, 2013				
lbrasil	1	100.0%	0.0%	lindia	21.5%	78.5%
	2	100.0%	0.0%		23.9%	76.1%
	3	100.0%	0.0%		24.0%	76.0%
	10	100.0%	0.0%		24.0%	76.0%

Another important point presented by Li, Greco and Chavis (1999) in their study of the shares traded in Hong Kong is that if there is an increase in the volatility calculated from the yield of the financial assets, the lead-lag effect also increases. Thus, in the second period a portion of the variance of the stock exchanges of the other members of the BRIC countries is explained by an unexpected shock in the Brazilian market, which is maybe a consequence of the financial crisis, whereby the environment of uncertainty and asset volatility tends to be higher.

5. Conclusion

This study aims to evaluate the existence of lead-lag effect between Brazil´s stock exchange with stock exchanges of the other BRIC members (China, Russia and India). This analysis was performed for two periods, before and after the global economic crisis that occurred in 2008, with the objective of determining if the crisis has altered the relationship between stock markets analyzed, based on the analysis of the lead-lag effect. Furthermore, when analyzing the co-integration test, it appears that the Brazil´s stock market did not have a long-term relationship with stock exchanges from China and Russia in the first period analyzed (March, 2004 to September, 2008). Nevertheless, for the three countries analyzed, it is found that the lead-lag effect is intensified in the second period (September 2008 to March 2013). On the one hand, the structural changes in the Brazilian stock exchanges contributed to greater integration with the other stock exchanges in the capital market, intensifying the effect of lead on the stock exchanges analyzed. On the other hand, the financial crisis and the risks associated with this crisis intensified the volatility of returns of financial assets and consequently the lead-lag effect between different markets.

Regarding the velocity of adjustment, they take about two days to be dissipated, proving the theory of EMH, which states that the information market are absorbed instantly, and that opportunities to earn abnormal profits through arbitrage between the markets are nonexistent. Moreover, it appears that the movements found in the stock indices of the stock exchanges of countries analyzed did not follow a stochastic process, because they are highly correlated and exhibit lags in their movements, strengthening the evidence of lead-lag effects between them. Regarding the Brazilian capital market, factors such as the reduction of the interest rate, the more efficient control of inflation and others have mitigated the risk of investments in shares of companies listed on the Ibovespa. Those changes have contributed to make Brazil market the benchmark capital of the BRICS.

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