IS THERE DIVERSIFICATION BENEFIT BETWEEN EMERGING AND DEVELOPED STOCK MARKET: EVIDENCE FROM THE BRIC AND US STOCK MARKET

by

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Abstract

This paper seeks to investigate the linkage and co-movement relationships between the stock markets of US and BRIC, and determine the degree of diversification benefits among them within the sample period from January 2001 to September 2017. The entire sample period is divided into three phases: pre-crisis, during crisis and post-crisis in order to be more comparative. The empirical results show that there is a strong linkage and co-movement relationship between BRIC and US stock markets, especially after 2007 financial crisis. Also, the upward long run conditional correlations demonstrate that the diversification benefits are weakened substantially. However, there is not any evidence showing the existence of co-integration between BRIC and US market for all three phases, except for the stock market of China during the crisis. Moreover, most of the BRIC stock markets are appeared to have no short term causality to US market.

Keywords: BRIC Markets; Diversification; Conditional Correlation; Linkage; Co-movement; Co-integration; Short Term Causality; Dependence; Pre-crisis; Post-crisis.

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1. Introduction

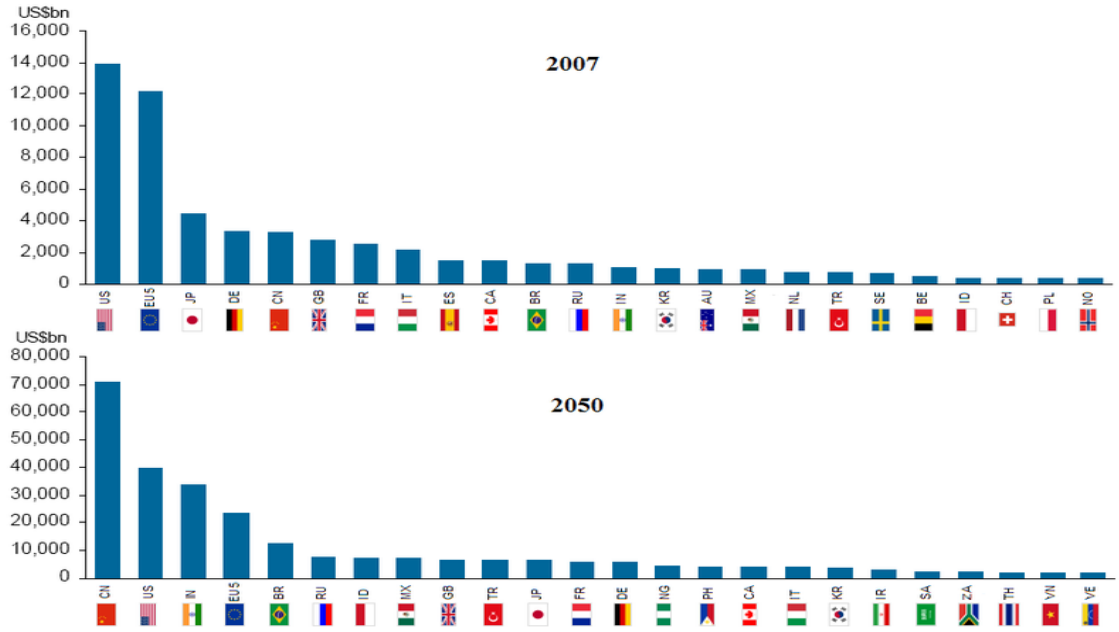
BRIC is a grouping acronym that refers to the countries of Brazil, Russia, India and China, which are all deemed to be at a similar stage of newly advanced economic development. It was coined by Jim O'Neill in 2001 and developing rapidly in these decades, and making huge contribution to the whole world and occupying more important status. BRIC has been trying the best to decrease the gap with developed countries. The graphs below show the current and expected influence of BRIC.

Figure 1-1

The figure shows some fundamental indicators of BRIC countries recorded in 2011, contains population, GDP, GDP average growth rate, exports and HDI change. The data is from World databank.

BRICs Development Indicators				
Indicator	***Brazil***	***Russia***	***India***	***China***
Population (2009)	194 mil.	142 mil.	1.15 bil.	1.33 bil.
GDP (US$, 2009)	1,573 bil.	1,232 bil.	1,310 bil.	4,985 bil.
GDP per Capita (PPP, Current Intl. $, 2009)	$10,499	$14,913	$3,015	$6,778
GDP Avg. Growth Rate (1990 - 2009)	2.5%	0.3%	6.3%	10.1%
GDP Projected Avg. Growth Rate (2011-14, as of April, 2011)	4.2%	4.5%	8.1%	9.5%
Merchandise Exports (US$, 2009)	153 bil.	303 bil.	162 bil.	1,201 bil.
HDI % Change (1990 - 2010; for Brazil only 2000 - 2010)	7.6%	3.8%	33.3%	44.2%
Global Sherpa, 2011 (www.globalsherpa.org); Data sources: World dataBank, International Monetary Fund (IMF), UNDP Human Development Report.				

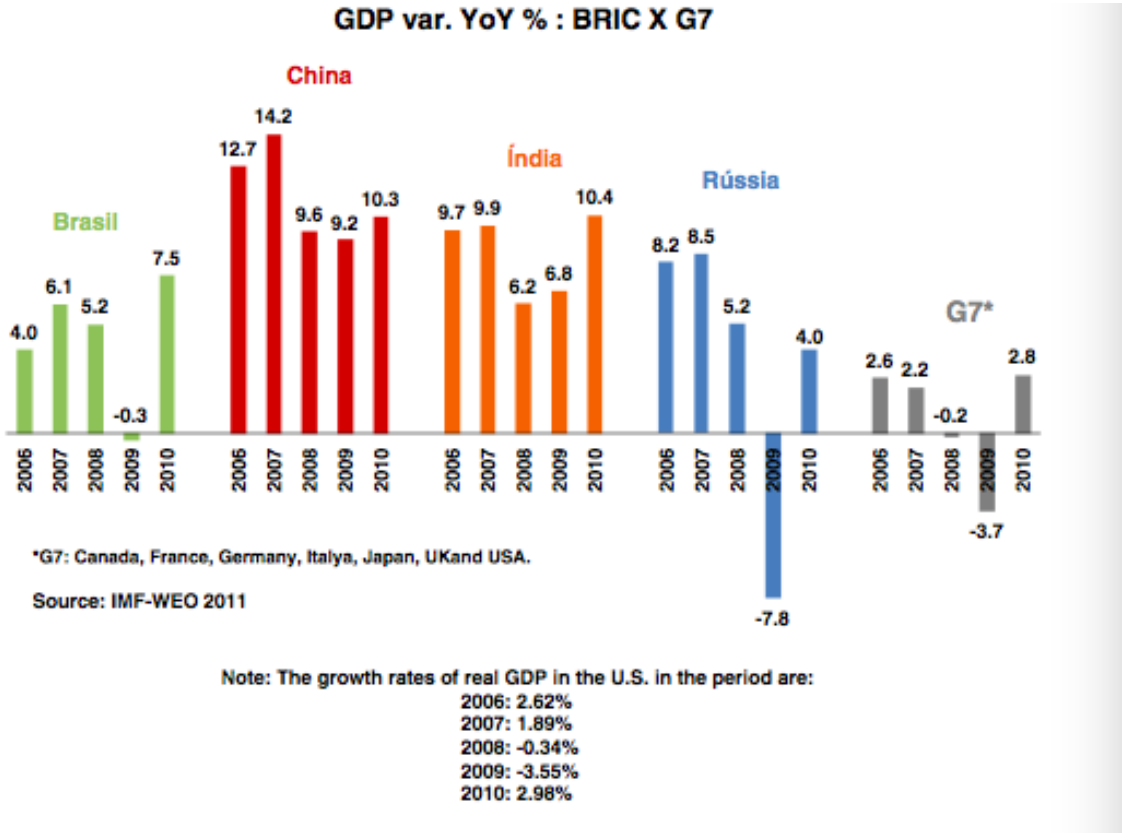
The figure shows the GDP of main countries in 2007 and their expected GDP in 2050. The top1 is the U.S in 2007 while the top1 will be China in 2050.



The four countries vary in their characteristics, economic and geopolitical importance. From the graphs above, China and India both have the most population and relatively closed and state-controlled capital markets. Their development strategy is export led, based on domestic industrialization for export markets. For the past decade, it can be seen that even though the net exports for China were relatively lower due to higher imports compared to the other countries, its year over year export growth has still dragged its GDP up in a faster pace. On the other hand, Brazil and Russia are primarily natural resource-based economies and well-known commodity exporters. Their capital markets are much more open and currently subject to relatively lower state controls.

Figure 1-2

The figure shows the growth rates of real GDP of BRIC countries (emerging country) and the G7 countries (developed countries) during 2006 to 2010, especially numbers are provided of four emerging countries and the U.S.



Note: The growth rates of real GDP in the U.S. in the period are:
2006: 2.62%
2007: 1.89%
2008: -0.34%
2009: -3.55%
2010: 2.98%

The global financial crisis that happened in 2007 had made a crash for most of the countries over the world, but how much it had influenced BRIC? From the graphs above, the answer is quite obvious as all of the four countries were influenced. Their GDP growth rates were declined in 2008. However, the degree of those declines was not the same. Russia and Brazil dropped sharply and the growth rates were negative in 2009, especially for Russia, as the crisis caused the prices of oil and gas to drop down while Russia is the country that deeply relies on the exportation of energy. Thus, Russia had taken a huge loss during the crisis period. For China and India, the crash seemed to be mild. The GDP growth rate of China dropped in 2008 but still had

9.6% and recovered quickly in 2009. India had very similar pattern to China, and it even got more growth in 2009 compared with 2008, which shows the great recovery ability.

Therefore, analyzing the long term and short term relationship between developed markets and emerging markets is important in today's world, especially under the condition of globalization that every country in the world has connected with each other. Since emerging markets have been becoming more and more important in the world, analyzing the relationship would not only be helpful for the countries' development, but also would give investors a concept of how to effectively invest worldwide.

This paper uses US stock market and BRIC stock markets as the study samples, each represent developed market and emerging markets. In terms of the timeline, the paper chooses the monthly data from 2001 to 2017 and divides them into three periods: pre-crisis, during crisis and post-crisis period. The data that will be used are from each stock market's main Index, S&P 500 for U.S, IBOV for Brazil, RTSI for Russia, SENSEX for India and SHCOMP for China. All of the closing prices on the index are denominated as US dollars to ensure the consistence. In terms of the structure, we will first present and review the relevant arguments and empirical results that have been found by the other professional researchers in their published papers. Next, several typical models will be used to test the empirical results based on our sample data. Meanwhile, we will apply some extra models to test new arguments that have not been done in our main reference paper, such as co-integrating and causality relationships, which will be introduced more detailed in the following paper. Lastly, the findings we have generated will be compared to the ones from other published articles and give the overall conclusion of the paper.

2. Literature Review

Nowadays, as the financial market has been increasingly globalized and the stock markets in emerging countries have been growing rapidly, more investors are seeking opportunities to diversify their overall portfolios' risks by investing funds in different countries. As a consequence, the research questions, such as whether having portfolios invested in developed and emerging markets together could truly provide diversification benefits, could the benefits exist in a longer period or just a flash in the pan, and what would be the factors that could affect the benefits have been studied popularly worldwide.

French and Poterba (1991) indicated that the international diversification benefits are able to effectively reduce the overall risks, and have been found in decades due to different market behaviors and movements within countries. On the other hand, Arshanapalli and Doukas (1993) presented their research paper and showed that the global stock markets tend to move in the same direction at the post-crisis period, and the diversification benefits would be weakened. In other words, financial crisis would have negative impact on diversification benefits. Generally speaking, the US stock market was considered to have the largest impact over the other developed or emerging markets. Zhang, Li and Yu (2013) also supported this argument in their research paper by showing that the diversification benefit could be reduced significantly due to the increase of time-varying correlation between countries when crises happened.

In this paper, we focus on researching and investigating the linkage and co-movement relationships between BRIC (Brazil, Russia, India, China) and US stock market within three different periods, and discuss the topic of will there be any diversification benefit between them.

As a matter of fact, several professionals have studied and given their arguments in this particular area. Dimitriou, Kenourgios and Simos (2013) presented a movement trend analysis for US and BRIC stock markets from 1997 to 2012, and showed that there was a strong co-movement among all five markets, especially after Lehman Brothers collapsed. In the paper, they also used FIAPARCH-DCC approach to test the degree of linkage and dynamic correlation from different periods. The empirical evidences showed that there was not obvious linkage between BRIC and US stock market during the early stages of the crisis. However, the linkage is being recognized gradually after the crisis, and there was an increasing trend on dynamic conditional correlation between the stock markets of BRIC and US. The main reasons given in the paper for this lagged contagion impact on BRIC stock markets are because of the high levels of accumulated foreign exchange reserves and significant budget surpluses those countries usually have, and also the lag of attentions that are brought to BRIC's investors as they considered the crisis as only a single-country case. Once the investors realized the severity of the crisis, they would change their risk appetite by cashing out the stocks, and it would produce higher correlation.

The similar results have also been presented in other public research papers. Bekiros (2014), Zhang, Li and Yu (2013) both demonstrated their arguments in the papers saying that the BRIC stock markets have been more internationally integrated and can be highly affected by US stock market after the 2008 financial crisis, and there was an upward long-run trend of correlation between them. Mensi, Hammoudeh and Kang (2017) adopted multivariate DECO-FIEGARCH model in their paper and showed that there was a significant time-varying correlated relation between BRIC and US stock market, particularly from early 2007 to summer 2008. Moreover, Yarovaya and Lau (2016) indicated in their paper that conditional correlations tended to be

pulled up when there was a negative shock caused by crisis on stock market. In addition, Kenourgios, Samitas and Paltalidis (2010) used both multivariate regime-switching Gaussian copula model and dynamic conditional correlation (DCC) to prove that BRIC markets would have large contagion effect from the market of crisis country, and the increasing linkage during the financial turmoil implied the high possibility of markets crashing simultaneously at that period of time.

Furthermore, In order to compare the specific degree of correlation between each stock market from BRIC and US, Dimitriou, Kenourgios and Simos (2013) applied the unconditional correlation test and found out that the stock market of Brazil was most correlated to US, whereas the stock market of China had the least correlation to US. The same argument has been given by Aloui, Aissa and Nguyen (2011) as they proposed that the dependency effects of US market is higher and more persistent on Brazil and Russia markets, but lower and less affected on China and India markets. The reason was because that the countries like Brazil and Russia are highly relied on exported commodity prices, whereas China and India are finished-products export orientated countries. Zhang, Li and Yu (2013) further compared the dynamic correlation and concluded that the correlation of stock markets between China and US has been kept lowest even during the crisis period. The reason was due to different macroeconomic trends between China and US.

After reviewing the essential literatures, there are strong evidences showing that the correlation and co-movement between the stock markets of BRIC and US have been gone higher, especially after 2007 financial crisis, and the diversification benefits have been weakened substantially since then. Moreover, the markets in Brazil and Russia appear to have much higher correlation

compared to the markets in China and India. Furthermore, the existence of large lagged contagion effect from the market of crisis country to BRIC indicates that investors would change their risk appetite as soon as the severity of crisis has been realized, and it would lead to even higher dependency between global markets. However, there are some extra tests we could add on based on the paper from Dimitriou, Kenourgios and Simos (2013). We could apply the co-integration model to test the long term co-integrating relationship between BRIC and US stock market. Also, it would be more comprehensive to test the short term causality between those markets, and determine whether or not the change on US stock market would have similar change on BRIC stock markets within a short period of time.

In the following paper, we will use different models to further test the linkage and correlation between BRIC and US market with different sample data, and compared the findings to the ones from previous literatures. In addition, we will test and determine the existence of long term co-integrating and short term causality relationship between US and BRIC markets in three different periods.

3. Data Selection

In this paper, most of the models and tests will be applied based on three periods as mentioned above, in order to be more comparative on the effects regarding the occurrence of financial crisis. We take the sample data from January 2001 to May 2007 as the indication of pre-crisis period, the data from October 2010 to September 2017 as for post-crisis period, and the rest of the data in between as for during crisis period.

4. Methodology and Empirical Results

In this section, we will first present the graphs of the movement trend for US and BRIC stock markets based on three periods in order to generally test and demonstrate the co-movement relationship between BRIC and US stock market. After that, we will show the overall descriptive summary statistics in terms of the mean and variance from each country with different periods, and determine the changes on the return and risk level of each market from pre-crisis to post-crisis period.

For the specific analysis of the relationship between US and BRIC markets, the Augmented Dickey Fuller (ADF) and Phillip Pheron (PP) unit root models will be used first to test the stationarity of the data based on both log returns and log prices. The null hypothesis of unit root test would be the data contain unit root, or are not stationary at level. If the tested data are not stationary at level, we will further implement Johansen co-integration model to test the long term associated relationship between those markets. The null hypothesis of Johansen co-integration model would be there is not co-integration between the variables. Once the long term co-

integrating relationship between US and BRIC markets has been determined, it would be comprehensive to test the two way causality relationship between those markets. Thus, Granger Causality test will be performed afterwards to demonstrate the existence of short term causality from either US to BRIC markets or BRIC to US market within different periods. The null hypothesis in this test would be there is not short term causality between the tested markets. Lastly, both unconditional and MGARCH dynamic conditional correlation models will be used to determine the change on degree of diversification benefit between each of BRIC and US stock market over the past 17 years, as well as to indicate which market has the most potential ability to diversify specific risks while taking with US market. By conducting the above tests in this order, it would be clearer and more smooth for the readers to understand the relationship between US and BRIC stock markets from the shallower to the deeper based on pre-crisis, during crisis and post-crisis periods.

4.1. Trend Analysis

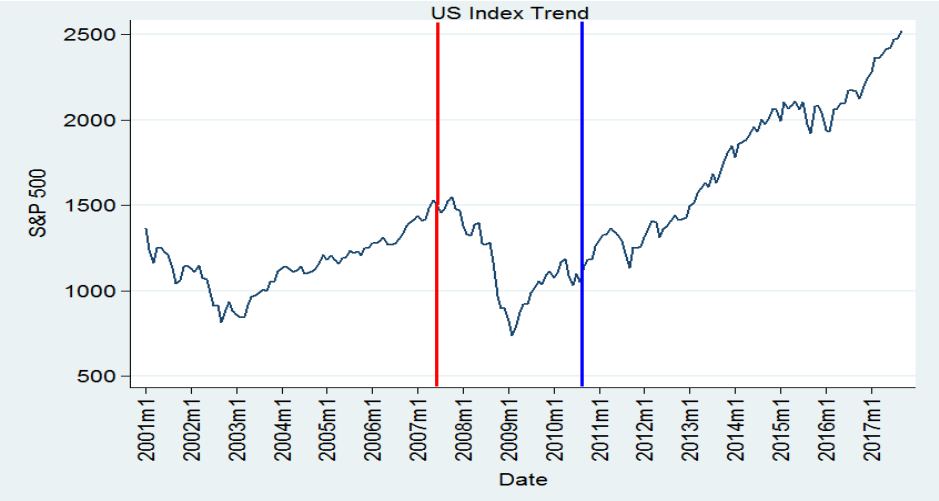
Figure 4-1 below shows the detailed index moving curves from 2001 to 2017 for all five stock markets. The red and blue vertical lines separate the graphs into pre-crisis, during crisis and post-crisis periods. As we can see from the graphs, the stock markets from BRIC and US have declined simultaneously when the crisis occurred, especially after Leman Brothers collapsed on September 15, 2008, which indicates the high level of contagion effect came from US subprime crisis. Among the five markets, Russia and Brazil appeared to be the ones that declined the most during the financial crisis. In the pre-crisis period, markets from Brazil, Russia and India were acting very similar to US market, but China was acting a bit differently. In the post-crisis period,

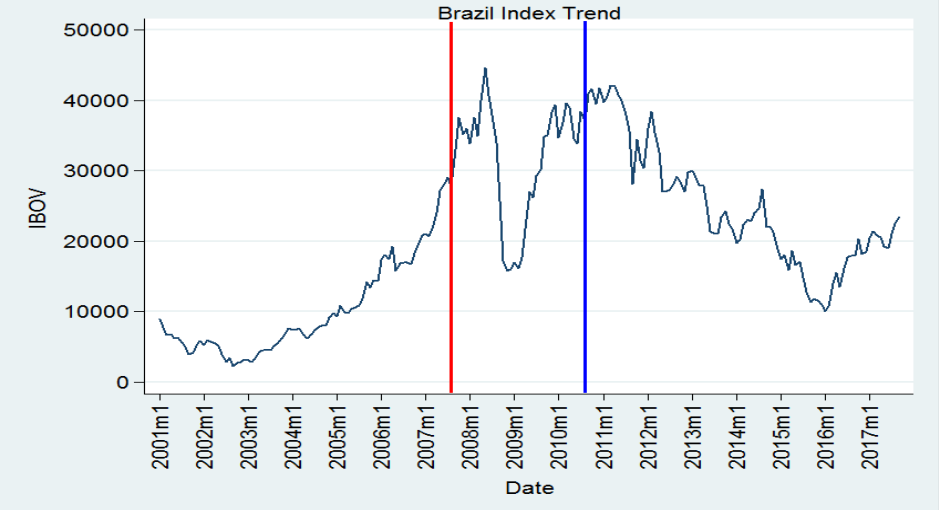
due to the recovery process, each stock market from BRIC was moving to the same direction as US market. However, there was a dramatic downturn for BRIC index from 2011 mainly due to European debt crisis.

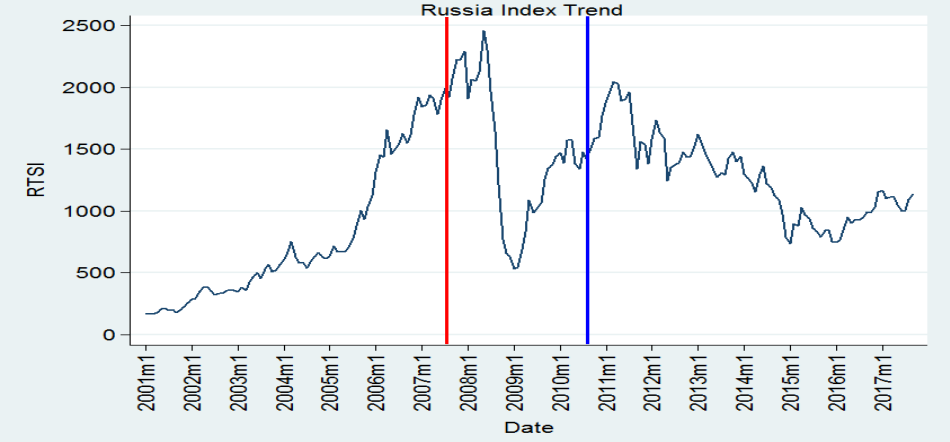
The movement trend of the five stock markets showing here are also consistent with the changes of their GDP indicated in Figure 1-2. As mentioned previously, the GDP growth rate from entire five countries has declined in 2008 and 2009 compared to the previous years, especially for Russia and Brazil, which had even negative GDP growth rate in 2009. Thus, the bad signal has caused panic for investors during that period as they were worried about the overall health of the economy and the corporates' profits. Eventually, it led to the downturn of their stock market index. According to the graphs, they show a strong co-movement relationship between US and BRIC markets, which is consistent to the results given by Dimitriou, Kenourgios and Simos (2013) in their research paper.

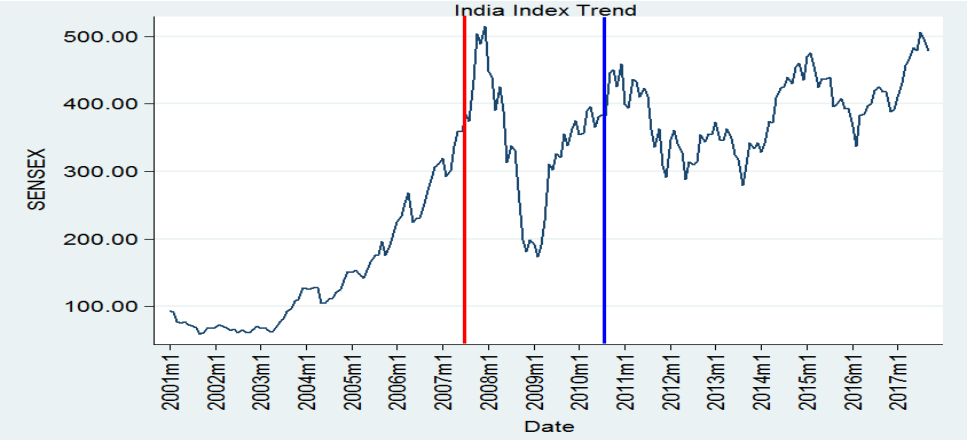
Figure 4-1: Price Movement Trend

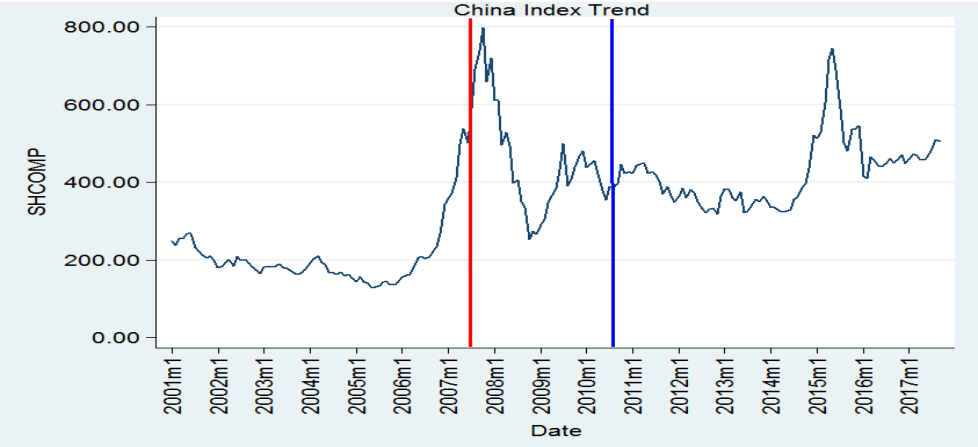
The following graphs show the price moving curve of five stock markets from Jan, 2001 to Sep, 2017. The red and blue lines separate the entire timeline into three periods: pre-crisis, during crisis and post-crisis.






Russia Index Trend
RTSI
2500
2000
1500
1000
500
0
2001m1
2002m1
2003m1
2004m1
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
2013m1
2014m1
2015m1
2016m1
2017m1
Date


India Index Trend
SENSEX
500.00
400.00
300.00
200.00
100.00
2001m1
2002m1
2003m1
2004m1
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
2013m1
2014m1
2015m1
2016m1
2017m1
Date


China Index Trend
SHCOMP
800.00
600.00
400.00
200.00
0.00
2001m1
2002m1
2003m1
2004m1
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
2013m1
2014m1
2015m1
2016m1
2017m1
Date

4.2. Mean and Variance Comparison

Figure 4-2: Summary Statistics

The following three tables sequentially represent the average mean, average standard deviation, max and min numbers from five stock markets at pre-crisis, during crisis and post-crisis period. All the numbers are calculated based on log returns.

Variable	Mean	Std.Dev.	Min	Max
USA	0.0015	0.0397	-0.1166	0.0829
BRZ	0.0146	0.1220	-0.4289	0.2497
RUS	0.0306	0.0818	-0.1761	0.1876
IND	0.0177	0.0729	-0.1938	0.1494
CHN	0.0101	0.0703	-0.1442	0.2461

Variable	Mean	Std.Dev.	Min	Max
USA	-0.0073	0.0617	-0.1856	0.0900
BRZ	0.0103	0.1228	-0.4000	0.2171
RUS	-0.0042	0.1391	-0.4491	0.2668
IND	0.0055	0.1164	-0.3201	0.3114
CHN	-0.0076	0.1160	-0.2815	0.1626

Variable	Mean	Std.Dev.	Min	Max
USA	0.0094	0.0312	-0.0745	0.1023
BRZ	-0.0066	0.0931	-0.2367	0.2648
RUS	-0.0034	0.0813	-0.2493	0.1956
IND	0.0008	0.0646	-0.1641	0.1760
CHN	0.0029	0.0693	-0.2701	0.1765

Figure 4-2 provides the descriptive statistics of BRIC and US stock market based on logarithmic stock returns in three different periods. As we can see from the first table, all of BRIC markets have much higher average mean, but also more risk compared to US market between 2001 and 2007, especially for Brazil and Russia markets, which demonstrates the fact that emerging markets have been growing in the much faster pace than developed market. When the big financial storm sweep across the world, all of the five corresponding markets went down simultaneously and got rebounded after the prices hit the bottom, only Brazil and India stock markets had positive average returns during the crisis period, which indicates that both of them had rebounded sooner and in a higher level compared to other markets. In the recovery period since late 2010, US market was recovered more steadily and with less fluctuation compared to BRIC markets as it had relatively higher average mean. The main reason was because of the big European debt crisis happened in 2011, which indirectly and negatively affected the other four markets.

The results generated here can also be seen on the moving curves from Figure 4-1 directly. By taking overall look at the mean and risk level for all countries, the stock markets of Brazil and India had the highest average mean, whereas the stock markets of Brazil and Russia are the most risky ones from the past 17 years.

The conclusions here are consistent to the findings from Dimitriou, Kenourgios and Simos (2013), as well as Mensi, Hammmoudeh, Reboredo and Nguyen (2014). Both of their research papers presented that the average means of Brazil and India markets and average risk of Brazil and Russia markets appeared to be higher compared to the other markets for the past decade.

4.3. Unit Root Tests

Figure 4-3: ADF and PP Tests with Log Returns

The reported numbers are p-values; significant at 5 percent confidence level (*); the lag length included in the models are based on Akaike information criteria; the above ADF and PP tests are based on model with both constant and trend. All figures are at level.

Variable	Pre-crisis		During crisis		Post-crisis	
	Log Return		Log Return		Log Return	
	ADF	PP	ADF	PP	ADF	PP
USA	0.000*	0.000*	0.000*	0.001*	0.000*	0.000*
BRZ	0.000*	0.000*	0.005*	0.005*	0.000*	0.000*
RUS	0.000*	0.000*	0.029*	0.024*	0.000*	0.000*
IND	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
CHN	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

Figure 4-4: ADF and PP Tests with Log Prices

The reported numbers are p-values; significant at 5 percent confidence level (*); the lag length included in the models are based on Akaike information criteria; the above ADF and PP tests are based on model with both constant and trend. All figures are at level.

Variable	Pre-crisis		During crisis		Post-crisis	
	Log Price		Log Price		Log Price	
	ADF	PP	ADF	PP	ADF	PP
USA	0.274	0.272	0.958	0.922	0.278	0.295
BRZ	0.171	0.171	0.916	0.767	0.901	0.895
RUS	0.296	0.229	0.956	0.836	0.491	0.406
IND	0.072	0.074	0.951	0.901	0.220	0.263
CHN	1.000	1.000	0.854	0.784	0.631	0.539

The stationarity for all the variables is tested with the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests in terms of both log returns and log index prices. The lag length is chosen based on Akaike Information Criterion (AIC). Since there has been an obvious trend throughout the entire period, thus both models are used with trend and constant. The main difference between ADF and PP test is that PP test uses non-parametric correction to test statistics, and it can be robust and more effective while testing with unspecified autocorrelation and heteroscedasticity (Fahami, 2011). The null hypothesis from both models is that the data contain unit root, or are not stationary at level.

According to the table in Figure 4-3, all of the reported p-values are less than 5%, which soundly reject the null hypothesis, and indicates that the log returns are stationary at level. However, the p-values based on log index prices from Figure 4-4 are way larger than 5%, which appear to be non-stationary at level, but stationary at first difference. The results we got here are consistent to the findings from Bekiros (2014) and Mensi, Hammoudeh, Reboredo and Nguyen (2014), as both of their papers have used the same unit root test with their selected samples to prove that all data based on log returns were stationary at level, but the data based on log prices had I (1) feature. Due to this special case, the further Johansen Cointegration test needs to be applied to determine whether or not there has been co-integrating effects within the data with log prices.

4.4. Johansen Co-integration Test

Figure 4-5: Johansen Co-integration Test

(*) indicates rejection of the null hypothesis of no-cointegration at 5% level of significance; r denotes the number of cointegrating vectors.

Variable		Trace Statistic						Max Statistic					
X	Y	Pre-crisis		During crisis		Post-crisis		Pre-crisis		During crisis		Post-crisis	
		r=0	r<=1	r=0	r<=1	r=0	r<=1	r=0	r<=1	r=0	r<=1	r=0	r<=1
USA	BRZ	14.544	0.104	10.217	1.973	7.239	1.479	**14.440***	0.104	8.244	1.973	5.759	1.479
USA	RUS	13.194	0.196	13.473	1.427	10.074	0.914	12.998	0.196	12.046	1.427	9.159	0.914
USA	IND	12.540	0.061	11.233	2.228	11.445	2.088	12.479	0.061	9.005	2.228	9.358	2.088
USA	CHN	12.458	0.001	**19.864***	3.016	7.203	1.963	12.457	0.001	**16.848***	3.016	5.239	1.963

As observed from figure 4-5, most of the BRIC markets did not have effect of co-integration with US market from three periods. China was the only one that contains one co-integrating vector during the financial crisis. Also, the results tested from trace statistic and max statistic regarding the co-integration between Brazil and US are appeared to be different in the pre-crisis period. Since the trace statistic is more powerful than max statistic, thus it can be concluded that there is not co-integration between Brazil and US. Overall, all of the BRIC markets did not have long-term relationship with US market for each period, except for China when the crisis occurred. The results we found here are different from the ones from other research papers. According to Bekiros (2014), it indicated that there was not any co-integrating vector between US and BRIC stock markets in both pre-crisis and post-crisis period. The main reason of causing the difference is that the author divided the entire sample time into two periods, instead of three periods like

what we did above. If we combined both during crisis and post-crisis periods together, the conclusion would have been the same. Another article of Fahami (2011) applied the same test and presented the completely opposite result of there was co-integration between those markets among all three periods. However, this paper was choosing different representative index as sample data, and all data were based on weekly. Therefore, those mismatches would have generated different results.

4.5. Short Term Causality Test

Figure 4-6: Granger Causality Test

The reported numbers in the table below are calculated p-values based on log returns; (*) represents rejection of the null hypothesis of no short-term causality at 5% level of significance; the lag length included in the models are based on Akaike information criterion, schwarz's Bayesian information criterion and Hannan-Quinn information criterion.

Variable		Granger causality wald test				Granger causality wald test			
X	Y	X----->Y				Y----->X			
		Total period	Pre-crisis	During crisis	Post-crisis	Total period	Pre-crisis	During crisis	Post-crisis
USA	BRZ	0.563	0.051	0.932	0.243	0.893	0.793	0.310	0.379
USA	RUS	0.986	0.151	0.543	0.322	0.162	0.771	0.018*	0.917
USA	IND	0.473	0.004*	0.873	0.145	0.620	0.213	0.883	0.478
USA	CHN	0.290	0.470	0.100	0.660	0.237	0.308	0.256	0.872

As there is not long term co-integration between US and BRIC markets, it would be necessary to apply Granger Causality model here to further test the two way short term causality relationship.

The lag one is selected based on AIC, SBIC and HQIC. The null hypothesis is that there is not any short-term causality relationship between the log returns of the variables. According to the p-values from above table, it can be seen that the null hypothesis can only be rejected from US to India before the crisis and from Russia to US during the crisis. In other words, the changes of US stock market would have the delayed impact on India stock market within a short period of time in the pre-crisis period, and meanwhile, the changes of Russia market would have the delayed impact on US market in the during crisis period.

In addition, when comparing the p-values from each of three periods, we can see that the values are generally higher at post-crisis than at pre-crisis, which indicates that the causality level has been weakened after the financial crisis. Overall, the empirical evidence is showing that any change of US stock market would not cause the similar change in most of BRIC stock markets within a short period of time. The results we found here turn out to be different from the ones argued by Xu and Hamori (2012). In their paper, they used AR-EGARCH model with daily sample data to present that US stock market had short term causality to the stock markets of India, Russia and China in pre-crisis period and had short term causality to the stock markets of Russia and India in the post-crisis period. The reasons that cause the difference are mainly due to different sample data selection and timeline division. Moreover, different model they used to test causality relationship could also cause inconsistence of the final results.

4.6. Lagrange-multiplier Test

Because of the difference on our results of short term causality relationship from others, the Lagrange-multiplier (LM) test for residual autocorrelation has been applied below to ensure the feasibility and suitability of the causality model we used above. The four tables from Figure 4-7 sequentially represent the data used from each of entire, pre-crisis, during crisis and post-crisis period. The null hypothesis is that there is not autocorrelation for the residuals at lag order. As we can see from all the tables, the null hypothesis cannot be rejected at 5% level of significance, and it concludes that it does not have any autocorrelation for residuals at lag order. In other words, the model used above is desirable and feasible.

Figure 4-7: Lagrange-multiplier Test

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	31.2523	25	0.18080

H0: no autocorrelation at lag order

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	25.7990	25	0.41839

H0: no autocorrelation at lag order

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	31.8102	25	0.16358

H0: no autocorrelation at lag order

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	27.1194	25	0.34995

H0: no autocorrelation at lag order

4.7. Unconditional Correlation Test

Figure 4-8: Pearson Correlation

The following three tables present the Pearson correlation between US and BRIC markets from three periods. All numbers are calculated based on log returns of stock index.

Pearson Correlation (Pre-crisis Period)					
Variable	USA	BRZ	RUS	IND	CHN
USA	1				
BRZ	0.73	1			
RUS	0.34	0.41	1		
IND	0.49	0.54	0.32	1	
CHN	0.14	0.17	0.21	0.14	1

Pearson Correlation (During crisis Period)					
Variable	USA	BRZ	RUS	IND	CHN
USA	1				
BRZ	0.79	1			
RUS	0.73	0.85	1		
IND	0.78	0.83	0.72	1	
CHN	0.45	0.57	0.42	0.58	1

Pearson Correlation (Post-crisis Period)					
Variable	USA	BRZ	RUS	IND	CHN
USA	1				
BRZ	0.54	1			
RUS	0.61	0.66	1		
IND	0.55	0.54	0.44	1	
CHN	0.38	0.36	0.22	0.23	1

Figure 4-8 shows the Pearson correlation based on the log returns between BRIC and US market for the pre-, during and post-crisis periods. It can be seen that all of the correlation coefficients are positive among three periods, which indicate that any change in US stock market would have positive correlated impact on BRIC markets. When we go into details, we can see that most of the return correlations between BRIC and US market were relatively lower before the crisis, except for Brazil (0.73). After the crisis broke out, the correlations have increased significantly, with the highest jump of 0.39 between Russia and US, and 0.31 between China and US compared to their correlations in the pre-crisis period. In the recovery phase, all of the correlations have gone back to generally normal degree, but are still higher than pre-crisis period. It can also be noticed that the correlation between China and US was quite low before the economy went down, and had been kept in a relatively lower level even after financial crisis. As a matter of fact, the foreigners were highly restricted to purchase Chinese shares on Shanghai Stock Exchange before 2014. However, since late 2014, the program called Shanghai-Hong Kong Stock Connect program was launched, and it allowed global investors to purchase shares listed on Shanghai Composite Index more easily (Hunter, 2014). Thus, the lower correlation between US and China stock market could provide more potential diversification benefits to global investors since then.

The results are consistent with the findings that Aloui, Aissa and Nguyen (2011) and Zhang, Li and Yu (2013) have given in their papers that the stock market in China was least correlated to US due to different macroeconomic trends, whereas Brazil market tends to have relatively higher correlations. However, there are still some different arguments. According to the findings from Bianconi, Yoshino and Sousa (2012), they concluded that the stock market in India has the lowest correlation to US, instead of China. The reason of causing this small difference may came

from different data selection and timeline division methods they used, as they used EMBI-India to represent India index, whereas we use SENSEX. Based on the above results, it can be clearly seen that the diversification benefits between BRIC and US market have attenuated substantially since 2007.

4.8. Estimates of the DCC-MGARCH Model

GARCH model is widely used to analyze the time-varying volatility of asset returns. According to Engle(2002), a return series r*i,t* can be generated by $r_{i,t} = u_{i,t} + h_{i,t}\varepsilon_{i,t}$ where $h_{i,t} = \omega_i$ $+ \text{¸}_i\varepsilon^2_{i,t-1} + \text{˘}_i h_{i,t-1}, u_{i,t}$ is the conditional mean which includes ARMA(p,q) terms of $r_{i,t}$ plus a constant, so that the demeaned return series will have iid standardized residuals $\varepsilon_{i,t}$ with a zero mean, and conditional variance of $h_{i,t}$. For the stock index return series, an ARMA (1,1) process is selected to mitigate autocorrelation.

We use the dynamic conditional correlation (DCC) model of Engle (2002) to estimate the covariance matrix of multiple asset returns. According to the paper written by Bianconi, Yoshino and Sousa (2012), the covariance matrix H_t for a vector of k asset returns in DCC can be written as:

$$H_t = D_t R_t D_t$$

$$R_t = \text{diag}\{Q_t\}^{-1/2} Q_t \text{diag}\{Q_t\}^{-1/2}$$

That is,

$$R_t = \begin{bmatrix} \frac{1}{\sqrt{q_{11}}} & 0 \\ 0 & \frac{1}{\sqrt{q_{22}}} \end{bmatrix} \begin{bmatrix} q_{11} & q_{12} \\ q_{21} & q_{22} \end{bmatrix} \begin{bmatrix} \frac{1}{\sqrt{q_{11}}} & 0 \\ 0 & \frac{1}{\sqrt{q_{22}}} \end{bmatrix}.$$

where D_t is the k ×k diagonal matrix of time-varying standard deviations from univariate GARCH models with $h_{i,t}$ for the ith return series on the ith diagonal. R_t is a time-varying correlation matrix.

The covariance matrix $Q_t = [q_{ij,t}]$ of the standardized residual vector $\varepsilon_t = (\varepsilon_{1,t}, \varepsilon_{2,t}, \ldots)'$ is denoted as:

$$Q_t = (1-a-b)\bar{Q} + a\varepsilon_{t-1}\varepsilon'_{t-1} + bQ_{t-1}$$

where $\bar{Q} = \{\bar{q}_{ij}\}$ denotes the unconditional covariance matrix of ε_t.The coefficients, a and b, are the estimated parameters depicting the conditional correlation process. $\text{diag}\{Q_t\} = q_{ii,t}$ is a diagonal matrix containing the square root of the ith diagonal elements of Q_t, the dynamic correlation can be expressed as:

$$\rho_{12,t} = \frac{(1-a-b)\bar{q}_{12} + a\varepsilon_{1,t-1}\varepsilon_{2,t-1} + bq_{12,t-1}}{\sqrt{[(1-a-b)\bar{q}_{11} + a\varepsilon^2_{1,t-1} + bq_{11,t-1}][(1-a-b)\bar{q}_{22} + a\varepsilon^2_{2,t-1} + bq_{22,t-1}]}}$$

We estimated the DCC model with two-stage estimation through quasi-maximum likelihood estimation (QMLE) to get consistent parameter estimates.

Therefore, DCC-GARCH model is a better method to test the time-vary correlation between two variants compared with normal GARCH model. In our paper, we intend to use DCC-MGARCH model to test specific time-varying correlation between the stock markets of BRIC and US from 2001 to 2017. Based on this, we are able to identify which stock market among BRIC provides the most diversification benefit while combined with US market. The figure 4-9 below shows the dynamic conditional correlation between BRIC and US market.

Figure 4-9: Dynamic Conditional Correlation

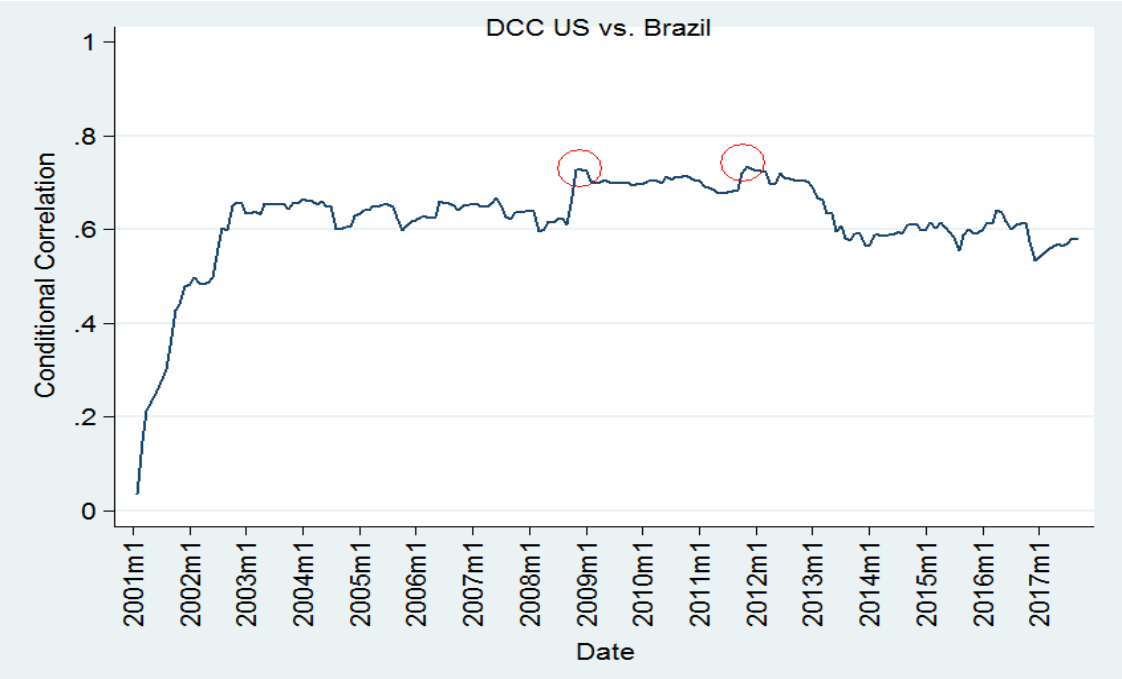
This table indicates the dynamic conditional correlation between US and BRIC stock markets from 2001 to 2017. All the numbers are calculated based on log returns of stock index.

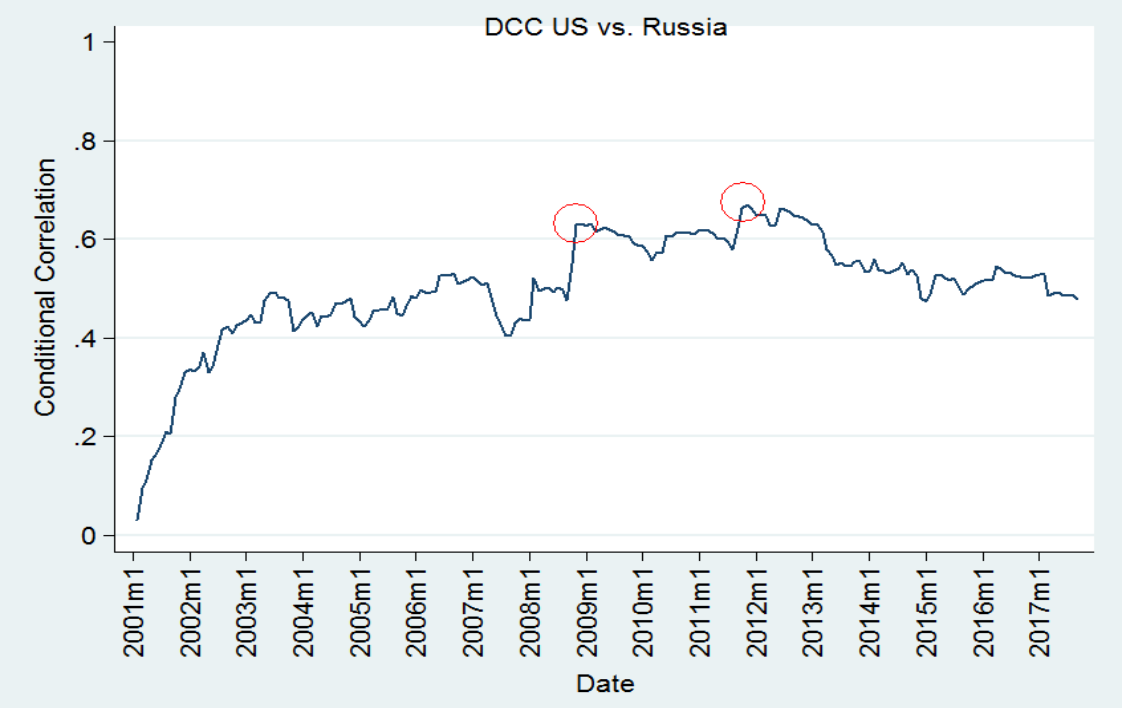
Variable	USA	BRZ	RUS	IND	CHN
USA	1				
BRZ	0.631	1			
RUS	0.614	0.745	1		
IND	0.647	0.691	0.563	1	
CHN	0.398	0.438	0.317	0.340	1

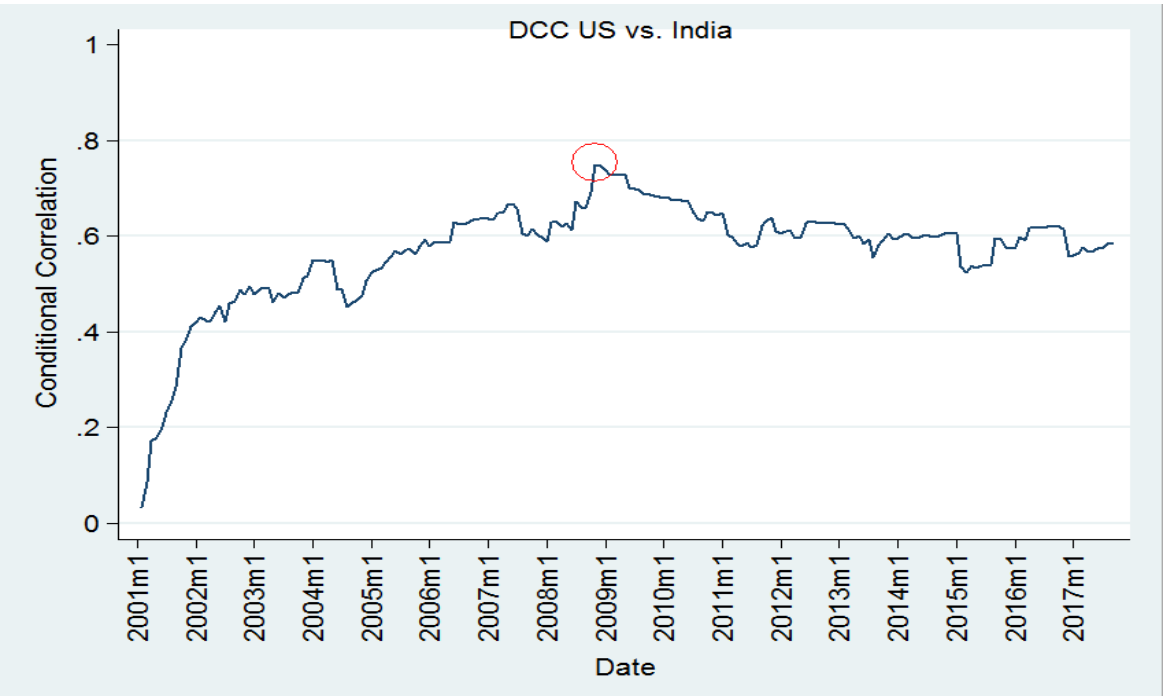
It can be seen from the table that China has the lowest correlation (0.398) with the US compared to the other three countries, and both Brazil (0.631) and India (0.647) have relatively higher correlation. The results above are similar to the results generated from simple correlation models.

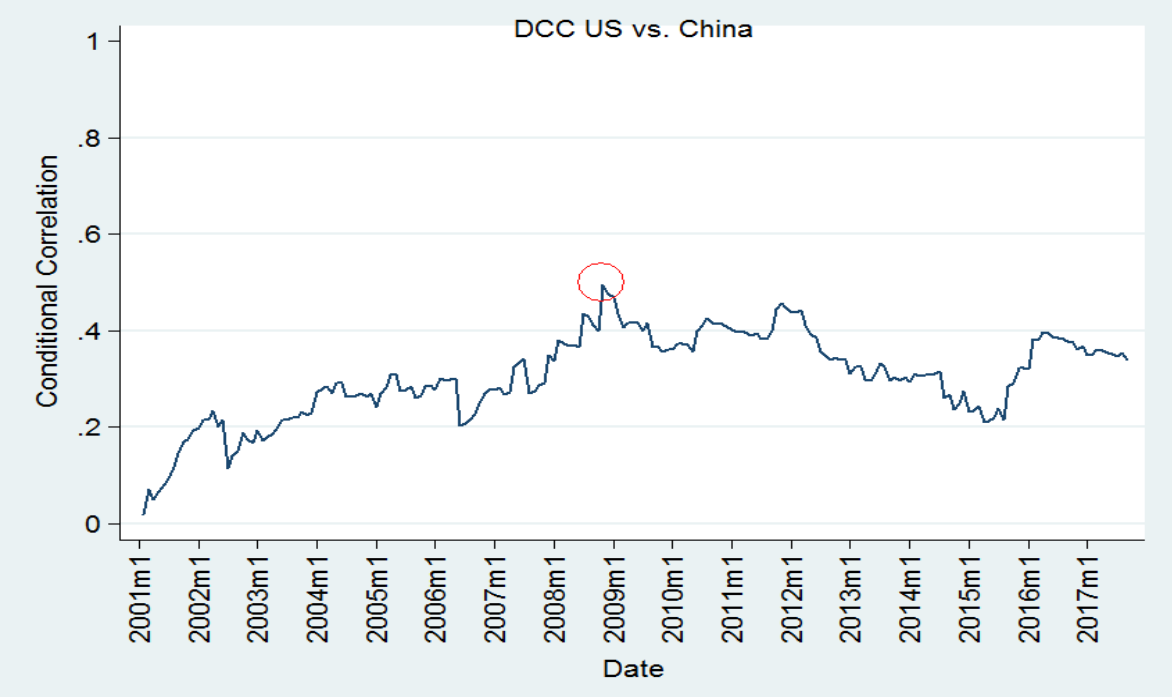
Figure 4-10: Conditional Correlation Moving Curve

The following four graphs present the time varying movement trend in terms of dynamic conditional correlation between US and BRIC stock markets from 2001 to 2017. The red circle represents the highest correlation at that point of time.






DCC US vs. India
Conditional Correlation
1
.8
.6
.4
.2
0
2001m1
2002m1
2003m1
2004m1
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
2013m1
2014m1
2015m1
2016m1
2017m1
Date


DCC US vs. China
Conditional Correlation
1
.8
.6
.4
.2
0
2001m1
2002m1
2003m1
2004m1
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
2013m1
2014m1
2015m1
2016m1
2017m1
Date

Furthermore, we plot the moving curves of dynamic conditional correlations between BRIC and US market as time basis from 2001 to 2017 on Figure 4-10. We can see from the graphs that all conditional correlations between BRIC and US have shown an increasing trend for the entire sample period, especially during the financial crisis. More specifically, the stock market in Brazil has the highest dynamic correlation with the US while China has the lowest in average due to specific economic development method that Chinese government has been imposing.

In addition, it can be seen from the graphs that both Brazil and Russia have two peaks (the places we circle in red in the graphs), one is in during crisis period, and the other is in post-crisis period, as both countries have suffered economic downturns in those two periods. However, for India and China, there is only one peak of the correlation during the financial crisis. Therefore, it can be concluded that any financial turmoil or economic downturn can significantly increase the correlation and dependence between emerging and developed market, and reduce the diversification benefits.

The empirical results we found above are consistent with the conclusion given from Dimitriou, Kenourgios and Simos (2013). In their research paper, the bivariate AR(1) – FIAPARCH(1,d,1) –DCC model was applied and estimated to summarize the t-Stat and APARCH under the relationship between the markets of BRIC. They indicated that crisis would push the increment of correlation between US and BRIC markets, and there was an upward trend of dependence between them, especially after Lehman Brothers collapsed in 2008. Moreover, the results here are also consistent with the paper authored by Yarovaya and Lau (2016), in which they did the research on stock market co-movements during the global financial crisis and found that crisis would pull up the correlation between the stock markets in different countries.

Figure 4-11: DCC-MGARCH Hypothesis Test

(*) represents rejection of the null hypothesis of there is no dynamic correlated relationship between two variables at 5% level of significance. All the calculated p-values are based on log returns of stock index.

Variable		**DCC-MGARCH**		
		Pre-crisis	**During crisis**	**Post-crisis**
		p-value	p-value	p-value
X	Y			
USA	BRZ	0.000*	0.000*	0.000*
USA	RUS	0.004*	0.000*	0.000*
USA	IND	0.000*	0.000*	0.000*
USA	CHN	0.213	0.006*	0.000*

The p-values calculated from Figure 4-11 are intended to double confirm the conclusions that have been generated above. The null hypothesis of this test is that there is no dynamic correlation between two variables. We use 5 percent as the level of significance, and any number attached with (*) indicates the rejection of null hypothesis. The test results above show that all of the stock markets from BRIC countries appear to have significant dynamic conditional correlations with the US market in three periods except for China in the pre-crisis period.

5. Conclusion

This paper is mainly focusing on the study of the short-term and long-term relationship between BRIC and US market, and determining the diversification benefits between them based on the data chosen from January 2001 until September 2017. The study period has been divided into three different periods: pre-crisis, during crisis, and post-crisis, in order to be more comparative. According to the models and tests, several important empirical results have been found. Firstly, there was a strong co-movement relation between the stock markets of BRIC and US. Secondly, US stock market has both lower average returns and corresponding risks compared to the BRIC markets, which indicates that the stock markets from BRIC have been growing rapidly within recent decades. Thirdly, according to Johansen Co-integration model, there is not any long-term relationship or any co-integration between BRIC and US market based on both log returns and log prices, except for China during the crisis period.

In terms of the short-term causality relationship based on the log returns, the tested results indicate that any changes on US stock market could only cause the similar short term change on India market before the financial crisis. Also, any changes on Russia stock market could cause the similar short term change on US market during the crisis. However, it does not show any sign of short term causality between those markets when taking the entire past 17 years all together.

Furthermore, the simple Pearson correlation model has been applied to demonstrate that the correlation between US and BRIC markets has been increased after the crisis, and it substantially reduces the diversification benefit for all the international investors. However, due to the unique economic development policies that Chinese government has been imposing, Chinese market has

still been correlated in the lower level to US compared to other three markets, which is able to provide more potential benefits in the long run.

In order to study and determine the time-varying correlation between US and BRIC markets, DCC-MGARCH model is used afterwards. The empirical results are quite similar with the ones we got from simple correlation models. Meanwhile, we found that all of the dynamic conditional correlations between BRIC and the US stock market have been rising sharply since 2001, and hit to the peak at the moment when the crisis occurred between 2007 and 2009, which demonstrate that financial crisis would truly change the investors' risk appetite completely and lead to contagion effects and produce higher than normal correlations.

In conclusion, the overall empirical results indicate that the co-movement and dependence between BRIC and US stock market have kept increasing for the past 17 years, which cause the diversification benefits between them to be weakened substantially over the time, especially after the 2007 global financial crisis. However, since it does not have any long run association between those markets, and they are not perfectly correlated with each other. Thus, the diversification benefits are still able to be realized for any investor who has longer investment horizon. Also, with the lowest correlation, the stock market in China appears to be the most attractive and potential option to be included in the portfolios with US market in order to best diversifying the specific risks.

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