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STOCK MARKET AND VOLATILITY SPILLOVER: EVIDENCE FROM VAR-GARCH ANALYSIS OF BRICS AND THE US

Master´s Thesis in Finance

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ABSTRACT

The thesis paper aims to investigate the volatility spillover effects from the stock market of the United States to BRICS (Brazil, Russia, India, China and South Africa). In this study I have employed VAR-GARCH framework on weekly return MSCI (Morgan Stanley Capital International) index of respective stock markets to analyze the volatility transmission mechanism between stock market of the US and BRICS. The data sample is divided into one full period from January 2000 to December 2016 and three different sub-periods as pre-crisis period, financial crisis period and post-crisis period. The result of VAR (1) - GARCH (1, 1) model employed to examine the volatility spillover between the US and the BRICS markets shows that most of the BRICS nations are affected during the global financial crisis period rather than the normal period. The result indicates that the presence of shocks transmission and volatility spillover during the global financial crisis 2007-09 is significant compared to the normal period. The result suggests that volatility spillover between the US and Brazil is high as compared to rest of the BRICS nations. The market of Russia, South Africa and China are affected relatively less than Brazil by volatility of the US market in the normal period. The presence of minimal impact suggests that most of the BRICS stock market behaves independently during the normal period. Moreover, the result shows that Russia is the most independent market followed by China during normal period despite of being affected by the US during the financial crisis. The findings also reveal that all BRICS market has significant effects of own-lagged past return innovations (shocks) and past conditional volatilities on their current volatilities. In addition, the evidence of short term influence of South Africa on the US can be used for further study on stock market interdependence of both markets. Furthermore, my study on stock market volatility during the normal period as well as financial turmoil period provides useful information to researchers, financial market regulators as well as investors to know the behavior of emerging stock markets.

KEYWORDS: volatility spillover, market efficiency, returns innovation, VAR-GARCH, financial crisis

1. INTRODUCTION

The world economy and financial system have always witness a significant change and shift in economic, financial and political power from one region to other along with the changes in financial and non-financial events around the world. The aftermath of the World War II followed by the cold war that provided a fear of communism to the United States and its alliances leads to formation of an informal group known as G7 (includes France, Italy, Japan, the UK, the US, Germany and Canada) to address the concerns regarding economic matters during mid-1960s to 1980. Russia joined the G7 group in 1998 and the group of seven countries became the group of eight nations which is known as G8. However, the invasion of Crimea by Russia in 2014 leads to suspension of its membership which challenged the future of G7. Furthermore, G20 was founded on 1999 in response to the Asian and subsequent global financial crisis. The group was formed with an objective to provide financial stability for a new world of globalized finance. The formation of the group even argues about the failure of G7 and G8 forums during such financial turmoil period and even discusses the idea of replacing the International Monetary Fund (IMF) (Kirton, 2013). However, the global financial crisis 2007-2009 brought new challenges to the global economy and proved that only having global economic forums is not enough to prevent such global crisis. The crisis paved a way for policymakers to find alternative economies and markets other than the developed ones. The crisis also highlights the interdependence between international stock markets and importance of new emerging markets in the global economy.

The concept of BRIC (Brazil, Russia, India and China) was introduced by Jim O´Neill for Goldman Sachs´s paper "Building Better Global Economic BRICs" in 2001. Later, the summit held at Russia in 2009 against the backdrop of global financial crisis 2007-09 channeled BRIC as a formal political-diplomatic entity. During the initial days of the BRIC notion, people argued with the idea about growth prospects and challenges posed by the BRIC to other global policymaking forums. The primary notion to build better global economies and arguments regarding the necessity of upgrading the global policy-making forums such as the G7and G20 for its effective functioning were put forward (O´Neill, 2001). Wilson and Purushothaman (2003) discuss the importance of BRIC's economies and forecast the dominance of these emerging markets in the world economy by the year 2050. The BRICS are considered as high growth

potential, fastest growing emerging countries and best choice for international investors. This has resulted in the increase of capital inflows in the BRICS financial markets from such investors' who wants to maximize and diversify their portfolio at international level (Bhuyan, Robbani, Talukdar & Jain, 2016).

The stock market crisis of 1987 brought lots of attention and interest among the general public, investors as well as academic scholars across the global financial market. Since then, we find various studies (Eun & Shim, 1989; Liu, Pan & Shieh, 1998; King & Wadhwani, 1990; Koutmos & Booth, 1995; Bessler &Yang, 2003; Liu, 2013) on interaction and interdependencies among stock markets to provide facts about the linkages between returns of major stock indices from all around the world. Similarly, since the introduction of BRIC concept in 2001, lots of study has been made to examine the financial and stock market linkage between different emerging nations, the BRICS and various developed economies such as the US, Japan, the UK (Diamandis, 2009; Cheng &Glascock, 2006; Kenourgios, Samitas & Paltalidis, 2011; Mensi, Hammoudeh, Reboredo & Nguyen, 2014; Lehkonen & Heimonen, 2014; Bianconi, Yoshino & Sousa, 2014; Singh & Singh, 2016). The extent of literature in the study of emerging nations´ stock market along with the BRICS suggests that in recent years numerous studies are focused on understanding the transmission mechanisms and studying the volatility transmission in times of financial crises (Forbes & Rigobon, 2001; Baekaert, Harvey & Ng, 2005; Rejeb & Boughrara, 2015). Moreover, the global financial crisis 2007-09 proved to be significant in the study of interdependence among international stock market (Zhang, Li & Yu, 2013; Fahami, 2011; Dimitriou, Kenourgios & Simos, 2013; Samarakoon, 2011) and to analyse the importance of emerging markets in the global economy.

Furthermore, it is important to have a quantitative measurement of the relationship between stock markets in order to assess the integration of local markets with the world markets and the degree of integration can be estimated with volatility transmission in the financial market (Forbes & Rigobon, 2002). The transmission mechanism of stock market can be studied basically in two areas, stock market returns and the volatility of stock market returns (Mukherjee & Mishra, 2010). The information transmission between markets can be measured through mean returns and volatility (Bhar & Nikolova, 2007). We need to study information spillover in terms of stock

market returns as well as volatility of the returns (Mukherjee & Mishra, 2010) in order to analyze the volatility spillover between two markets.

The global financial turmoil causes lots of vulnerability to the developed as well as emerging nations as a result of dramatic and rapid ups and downs in stock market return during the crisis period. International investors and policy makers need to know the movement of stock price indices in the developed as well as the emerging markets to minimize risk associated with any sorts of abnormal events in the financial market. We know that such fluctuations and changes in volatility of financial markets have significant effects on formulation of appropriate investment strategy for portfolio diversification and to mitigate any sorts of risk from financial crisis. Similarly, as volatility is synonymous with risk, we need to understand the volatility of stock markets which will help to determine the cost of capital and assess the investment and leverage decisions (Bala & Premaratne, 2004). Therefore, it is very important to find out the nature and behavior of stock market returns and find out how market reacts to the financial crisis and to measure the level of impact on stock markets.

1.1. Purpose of the study

The study aims to assess the impact of the US on stock market of emerging nations. Since the era of financial liberalization during the 1990s, the integration process among financial markets started to increase which implies that there is a gradual increase in co-movements between international markets. However, investor started to search for an alternative market to increase profit from portfolio diversification since the phenomenon of the US financial crisis in 2007. International investor started to study investment opportunities and potential markets for international portfolio diversification and the BRICS became an important priority for them as they were looking for such emerging economies to be integrated with the developed ones. Therefore, the study on the BRICS will provide valuable information to international investors and portfolio managers to manage their portfolio and financial risks. My study also aims to contribute on literature about the transmission of volatility from the US to all five BRICS nations with the help of Vector AutoRegressive-Generalized AutoRegressive Conditional

Heteroskedasticity (VAR-GARCH) framework, since I found that most of the study has focused only on the BRIC and South Africa is excluded.

The global financial crisis 2007-09 in the aftermath of the US housing bubble brought lots of attention not only to investors, researcher and policymakers but to general public as well. A normal person who might be new to the financial market might not be aware about the level of impact that she/he is going to bear from the sharp rise and/or fall in the stock market. The short-term nature of the market that keeps on moving up and down might confuse a normal person (Natarajan, Singh & Priya, 2014). The result in the figure 1 provides the evidence of fluctuations in stock market returns of the BRICS and the US stock markets during the period of financial crisis 2007-09.The nature of the crisis made clear that any change in one market is going to have an immediate impact on another market. The crisis provides evidence to extreme dependence structure of financial markets and it has been proved to be important in the study of cross-market correlations and information transmission and effects of past shocks from one market to another (Aloui, Aïssa & Nguyen, 2011).

Furthermore, being a student of South Asian region, I am intrigued to know the level of impact that the US holds on two of the most politically and economically influential economies of the recent time period. The BRICS nations have various trade agreements with the US. Similarly, the US is one of the major trading partners of BRICS nation through the years. And I believe the study is relevant in context of the recent BRICS summit held at China in the aftermath of political feud between China and India. It also highlights the increasing influence of these two big nations and the role played by the BRICS countries in the global economy. Therefore, I hope study on the BRICS will provide an insight on how stock returns volatility is transmitted to the BRICS stock market from stock market of the US in the pre-crisis period, during 2007-09 financial crisis and aftermath of the crisis.

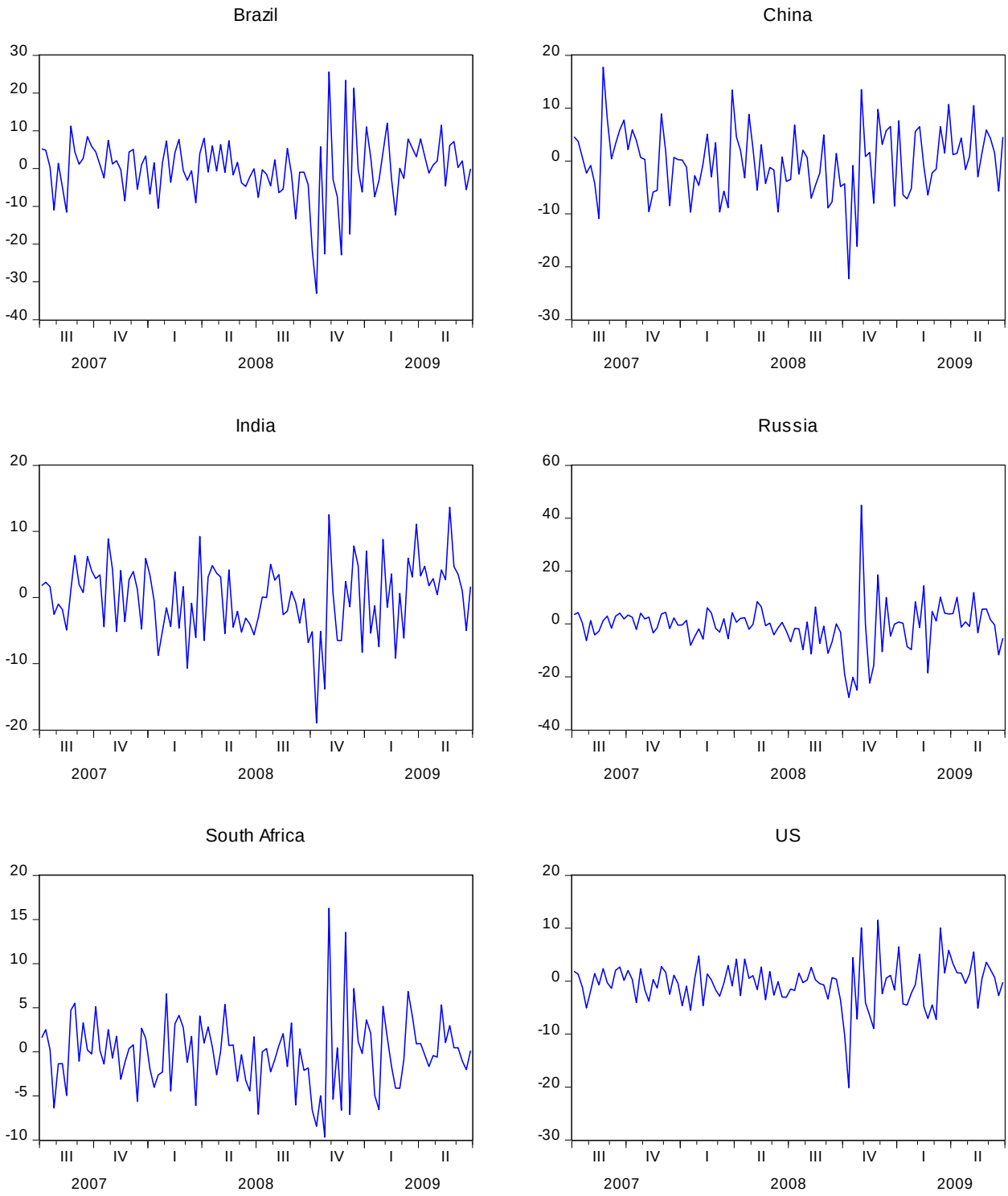

Figure 1. Weekly stock market returns during the financial crisis 2007-09.
(Data section 4.1 defines July 2007 to June 2009 as crisis period. In date axis:
I - January to March, II - April to June, III - July to September, IV - October to December).

1.2. Research hypotheses

The thesis models the dependence level between the stock market of BRICS nation and the US by assessing the impact of the global financial crisis and its impact on the performance of both stock markets. I propose following hypotheses for my thesis:

Hypothesis 1: The presence of volatility transmission from stock market of the United States to BRICS stock market is strong.

As my thesis aims to find out the existence of volatility spillover and level of impact from stock market of the US to stock market of BRICS nations on account of the financial crisis 2007-09, I propose my second hypothesis as:

Hypothesis 2: The volatility spillovers tend to increase during the crisis period.

1.3. Research structure

The structure of my thesis paper is organized as follows: section 1 covers the introduction about the thesis topic that provides a background on subject matter and purpose of my study. Section 2 provides an outlook on the economy and stock market of the BRICS, the US and performance of respective economy in the global context with brief history of the emerging nations. Section 3 discusses the theoretical background and a literature review of the previous studies on the stock market of emerging nations and the developed economy. Section 4 describes the data. In addition, it presents a preliminary statistical analysis and explains the research methodology used in my thesis. Section 5 of my thesis presents the empirical results obtained from methodology used for my data sample. This section analyses and discusses the estimation results in context of the global financial crisis 2007-09 as well as pre-crisis and the post-crisis period. Section 6 provides a conclusion to the research paper.

2. BRICS AND THE GLOBAL STOCK MARKET

The idea of BRIC proposed by James O'Neil at Goldman Sachs in 2001 brought lots of interests during the time regarding the growth prospect of BRIC economies and its influence in the global financial market. O'Neil coined the idea of BRIC in his paper for Goldman Sachs, "Building Better Global Economic BRICs" and discusses the nature of global economy with emphasis on emerging market's economies. Since then, the projection made by O'Neil regarding the growth of BRICS economies is proved by continuing growth of the BRICS markets and its increasing influence on the global economy. This chapter looks into brief history of the emerging nations and rise of the BRICS as a symbol of such emerging economies. It discusses about the rise of BRICS as an alternative for international investor and global economic policymaking forums. Along with that, it covers facts about the BRICS stock market and gives a brief outlook into the US economy and stock market.

2.1. Global economy and rise of the BRICS

The introduction of international monetary system after the World War II, transformations of financial deregulation era with financial liberalization and the creation of financial products and instruments during 1970s and 1980s, and subsequent developments on almost every aspects of the world economy during past few decades of the century has shown a significant shift in economic power from previous big players like the United States, Western Europe, and Japan towards developing nations and emerging markets. Moreover, the establishment of International Monetary Fund in 1945 and the General Agreement on Tariffs and Trade (GATT) in 1947 lays the foundation for financial liberalization which paved the way for gradual increase in the global trade and financial openness. Similarly, time and again, whether it's G7, G20 or the IMF, the role and significance of such global economic policy forums have been challenged by various global economic disturbances mostly occurred during the last 30 years. The challenge and need to upgrade G7 for effective global policy making (O'Neil, 2001), the formation of G20 as an alternative group of developed and developing nations in response to the Asian financial crisis

which spread to rest of the global economy and the global financial crisis 2007-09 are few reasons which have brought and placed the modern world economy at different context. These all circumstances have change the perspective of major economic leaders and groups as well as individual investor, financial institutions and research personnel regarding the importance of emerging economies over the last two decades.

When Jim O'Neill introduced the idea of BRIC (Brazil, Russia, India and China) in November 2001, he suggested a broader outlook into emerging markets with focus on these four economies. He emphasizes the relationship between the advanced economies and the BRIC with other emerging markets from all continents excluding Africa. However, he put much attention on growth prospects of the BRIC, their share in the world GDP and suggests for coordination between G7 and the BRIC economies. The growth prospects of BRIC posed threat to G7 and O'Neill even suggests for reformation of the G7 and considered the BRIC economies to play significant role in the global economy.

Over the past two decades, the BRIC economies have increased their contributions to the global market. The forecast to grow more than the US and G7, and the projection made by various researchers is proved by continuing growth of the BRIC economy. The BRIC comprised about 8 percent of global GDP at current prices, and 23.3 percent on a PPP basis at the end of 2000, that was somehow higher than both Europe and Japan (O'Neill, 2001). Similarly, the projection of Chinese economy to surpass the US in 2026, and the BRICS together to surpass the US in 2016 and the G7 in 2032 (Wilson, Trivedi, Carlson & Ursua, 2011), suggests the continuous shift of global economic and financial activity towards emerging new markets and the BRICS. The 10 percent accountability of the BRIC economies to the global GDP based on PPP during 1980s and 1990s increased to 25 percent in year 2010 which is projected to reach around 40 percent by 2050 (Wilson, et al, 2011). Furthermore, the GDP of China alone has increased drastically to become larger than the rest of the group combined together since 2007-09 financial crisis and since 2010 it has exceeded Japan's GDP that made China as the second largest economy in the world after the US. The significant increase of China's economy and modest increase of India as compared to rest of the economies shows the growing influence of China and India in the global economy.

Table 1 provides details about state of the global economy and size of Gross Domestic Period (GDP) based on Purchasing Power Parity (PPP) and current prices based GDP for the period from 2000 to 2016. The US holds bigger size as compare to rest of the country. China is the second largest economy (PPP based GDP) as compared to rest of the individual economies and largest among rest of the BRICS nations. China was larger than some individual G7economies such as Italy and Canada during 2001 and surpassed Japan in 2010 (current USD prices). The table shows the economy of BRICS is even larger (PPP based GDP) than EU (European Union) which comprises twenty-eight European nations. Although the GDP size is different based on current USD prices, the BRICS economy has increased in huge amount as compared to the EU and some of its member nations.

Table 1. Comparison of GDP size based on PPP and current prices.

	GDP based on PPP*					USD at current prices*				
	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
US	10,285	12,275	14,719	16,155	18,624	10,285	12,275	14,719	16,155	18,624
EU	11,751	13,827	16,947	17,770	20,031	8,914	13,795	19,203	17,288	16,448
G7	21,894	25,606	30,483	32,921	37,291	22,026	27,255	33,314	35,141	35,516
BRICS	9,337	13,238	20,864	28,862	37,729	2,762	4,221	9,596	15,469	16,873
World	49,879	62,645	83,505	99,664	120,197	33,823	43,888	63,650	74,489	75,368

Source: IMF. *Values are billions in USD

During the last decade, the world economy has witnessed a gradual rise of the BRICS economies; particularly the BRIC's swift recovery from 2007-09 financial crisis made them a significant force in the global economy as compared to other emerging markets around the world. The BRICS economies share of global GDP (PPP based) has increased from 18 percent in 2000 to more than 31 percent in 2016, and currently China alone holds about 18 percent share of total global GDP which is even more than the US, i.e., about 16 percent (IMF, 2017).The increasing share of China shows the influence of China's economy on global economy which is considered as a major challenge to G7 and other global economic policymaking forums.

The economic and structural reforms made by the BRICS nations support the continuous growth of the BRICS economy. The economic reforms by china in 1980s and 1990s, and economic

liberalization in 1990s by India in terms of openness to foreign direct investment (FDI) and modernization of stock market contributes a lot to improve the relation with rest of the world economy and increase their share in the global trade. The economic reforms and initiations for foreign trade liberalization by Brazil during mid-1990s which is also known as economic stabilization plan or price stabilization process to control inflation and to increase the confidence level of domestic as well as foreign investors proved to be essential in increasing their share in the global economy. Similarly, the economic restructure programs initiated by Russia during the 1990s in the aftermath of Soviet Union collapse includes privatization, trade liberalization and the IMF membership in 1992 which paved a way to get support for the stabilization process and control fluctuation of the Russian currency. The economic and trade reforms initiated by respective BRICS nations proved to be fundamental in improving economic environment, and performance of the individual country and overall BRICS economies.

Figure 2 depicts the growth and influence of the BRICS economies as compared to some of the major global economic policy making groups. The GDP growth of the BRICS economy is positive and high as compared to rest of the economy. The financial crisis of 2007-09 is considered as one of the major setback for growth of the global economy. The crisis affected smooth functioning of economic activities and growth of the emerging as well as advanced economies declined during the crisis period. The global GDP growth rate in 2016 is considered as lowest one since 2009 and OECD (Organization for Economic Co-operation and Development) projects modest global GDP growth of about 3.7 percent in 2018 compared to 3.6 percent in 2016. The growth prospect is assessed as improvement in policy level of some emerging market as well as advanced economies. The GDP growth rate of the US is projected to be about 2.2 percent in 2017 and near about 2.5 percent in 2018. Japan as a member of G7 nation is expected to have more than 1 percent of growth particularly as a result of growth in export in the Asian market. The GDP growth of the Euro area is forecasted to grow by 2.4 percent in 2017 and 2.1 percent in 2018 which could be weak in coming years as an effect of Brexit vote and uncertain future of the European Union and its relationship with the UK (OECD, 2017).

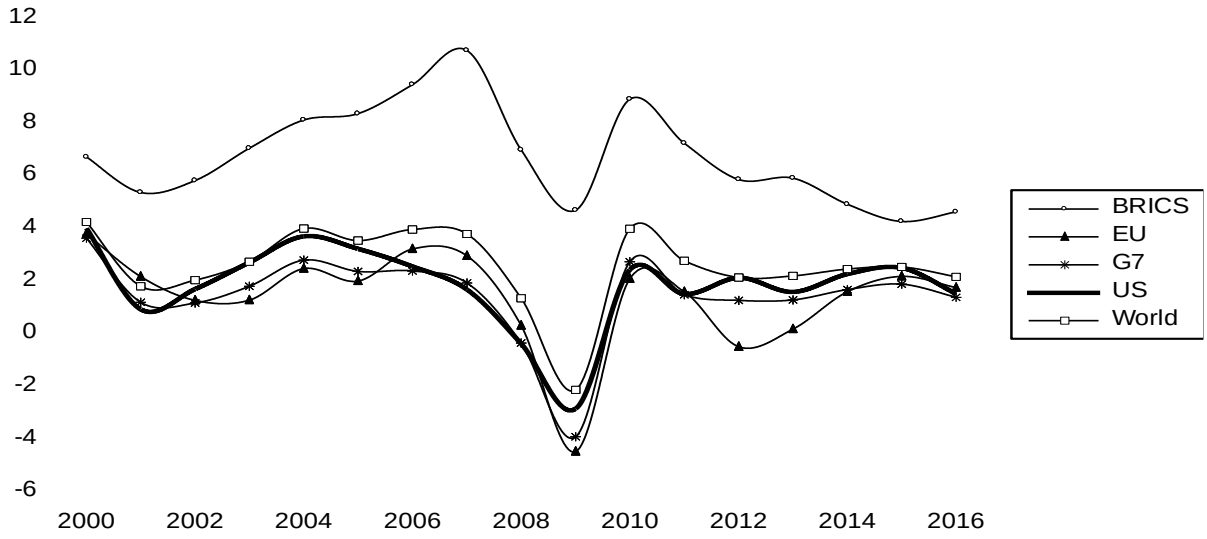

Figure 2.GDP growth rate (Annual average, %).
Source: (United Nations Conference on Trade and Development, UNCTAD)

The economic reforms and trade liberalization efforts initiated by respective BRICS nations are considered as a primary reason for gradual increment of the BRICS' share in the global trade. The growth of these culturally and geographically diverse BRICS countries also have been significant and influencing to the world economy in terms of population demographics, current account balance, forex reserves, flows of FDI and the global trade. In fact, the last 20 years of the global economy and international finance market has gone through lots of ups and downs with economic and financial crises that has led to rise of many emerging markets. The Asian Financial crisis in year 1997, dot com and tech bubble in 2000, the US sub-prime mortgages crisis of 2007 followed by the global financial crisis 2007-09 and the European sovereign debt crisis in 2010 has changed the whole environment of the modern global economy.

2.2. The BRICS economy and stock market

The birth of BRIC concept in 2001 brought government from respective countries to take initiation for creation of BRIC as a formal group in 2006 which formally became BRICS in 2010 as South Africa became the latest country to join the group. The BRICS forum was officially organized in 2011 summit held in China. However, the inclusion of South Africa raised number

of questions regarding the size and influence of the economy in the global context. Despite the politics and economics dissimilarities among the four BRIC countries, joining of South Africa being the smallest country in terms of geographical size and amount of contribution to the world GDP is considered as an attempt to increase BRIC position in the African continent. In total, the BRICS account for more than 40 per cent of the global population and nearly about 30 percent of the land mass (Ministry of Finance, Government of India, 2012). Table 2 provides an overview of the BRICS nations which includes social and economic characteristics of emerging economies as of year 2016. The average inflation of Brazil is 7.8 percent since 2003 and central bank of Brazil was able to reduce inflation to 3 percent in 2006. However, the increase in electricity prices, transportation costs and depreciation in its currency has significant impact on inflation that led to sharp rise in inflation rate. The economic crisis of 2014 as a result of trade sanction by the US and its allies proved to be costly and consumer prices soared up in Russia. Since then, it has stabilized the inflation around 7 percent.

Table 2. Social and economic variables of the BRICS as of year 2016.

	Population (million persons)	Inflation (CPI) Total, Annual growth rate (%)	Per capita GDP (US$)	GDP annual growth (%)
Brazil	209.568	8.74	8, 454	-3.60
Russia	143.440	7.05	8, 948	-0.50
India	1,326.802	4.94	1, 715	7.30
China	1,382.323	2.00	8, 234	6.70
South Africa	54.979	6.33	5, 309	0.60

Source: UNCTAD.

Russia has huge amount of natural resources (basically oil, natural gas and uranium). Along with natural resources, the privatization of industrial and agricultural sectors during 1990s after the end of Soviet Union has contributed a lot to make Russia as one of the economically as well politically powerful country after the US and China in recent time period. Despite being one of the largest economies, India is one of the mostly populated country and has lowest per capita GDP among the BRICS nations as a result of high unemployment rate. Despite low per capita GDP as compared to rest of the BRICS economies, India is growing its demand and well integrated within the global economy. Since 2003, the increment of productivity in manufacturing sector has contributed a lot in increasing productivity growth and for more than

half of economy's overall growth which ultimately has been the foremost reason behind high GDP growth. Similarly, the recent phenomenon of demonetization in India seems to have less adverse impact in its growth and expected to grow more than 7 percent in 2018. India has taken various measures in recent years to improve its financial market and investment environment. The introduction of goods and service tax, and structural reforms in financial as well as production sector is expected to accelerate growth of the Indian economy in the future. Goldman Sachs forecast that India will become the largest economy (GDP size based on US Dollar) after China and the US by 2050 (Wilson, et al., 2011). The GDP growth in China is projected to grow about 6.5 percent in 2018. The policy initiated by the Chinese government to support public investment and credit market is considered as primary reason for growth of Chinese economy in coming years. The negative GDP growth rate of Brazil in 2016 reflects the country's longest recession period. However, it is expected to grow progressively in upcoming years with gradual increment in the production of soy beans, iron ore, raw sugar and crude oil as these products are the major source of Brazil's export which contributes a lot for their trade balance (OECD, 2017).

In the last two decades, there has been a significant change in composition of the BRICS trade due to structural and technological developments across various sectors of the global economy. Similarly, the economy of BRICS nations has been a crucial part of the global economy for radical transformation of the world trade (Keeler, 2012). The increase in interdependence among the BRICS countries as well as with global economy has facilitated respective BRICS economies to increase their share in the global trade and exploit the opportunities for economic development and growth. Table 3 provide details of the BRICS countries' share in the global trade of merchandise as well as trade in commercial services which includes transport sector, and service sector such as construction and information technology. China increased its share in the world exports from 7 percent to 15 percent, as India has a modest rise from 4 percent to 6 percent from 2000 to 2012 (World Trade Organization, WTO, 2014). Similarly, the BRICS economies are famous for export of primary products as the BRICS nations comprise huge amount of natural resources. The export of BRICS nations also consists of manufactured products as well as technology based goods and services.

Table 3. Summary of merchandise trade and commercial services as of year 2016.

	Merchandise Trade		Trade in Commercial Services	
	Share in world exports (%)	Share in world imports (%)	Share in world exports (%)	Share in world imports (%)
Brazil	1.16	0.89	0.68	1.31
China	13.15	9.83	4.31	9.58
India	1.65	2.22	3.35	0.28
Russia	1.77	1.19	1.03	1.55
South Africa	0.47	0.57	0.29	0.31

Source: WTO.

In the last 20 years, the share of manufacturing as well as service sector has increased significantly being the major source of economic growth for country like China and India. Likewise, the process of economic liberalization and industrialization in the BRICS economies over the last decade reflects increase in import of capital goods as well as commercial services. The huge amount of natural minerals makes Russia dominant in export of oil and gas. India and China import huge amount of oil and other natural minerals from Russia. South Africa produce large amount of platinum and chromium. They have huge reserves of other minerals as well, such as manganese, vanadium and aluminosilicates (Ministry of Finance, Government of India, 2012).

2.2.1. The BRICS stock market

In the last two decades, financial markets evolved through financial liberalization and integration procedure that has made lots of contribution in increasing volume of the global trade. Moreover, the trend of market liberalization and securitization has affected the growth prospect of emerging economies as well as their financial markets. And changes made by the BRICS in monetary as well as fiscal policies, trade and foreign investment policies to make their economy more open and liberal has resulted to rapid rise of trade in goods and services, foreign direct investment and capital flows, both inside and outside of the BRICS economies. Similarly, growth of the BRICS in terms of market liberalization and development of stock markets subsequently turned those markets to an attractive destination for international investors who want to diversify their portfolio. Furthermore, the increase in FDI and capital flows brought cross-border and direct

investment equity flow as an important source of external financing for emerging countries in several forms such as direct equity purchases by investors, issues of rights one equities held by depository institutions in the form of American Depository Receipts (ADRS) and Global Depository Receipts (GDRs) and direct foreign equity offerings (see Claessens, 1995).The increase of equity financing in the BRICS economy along with transformation of financial markets and developments in functioning of stock markets relatively increased the capitalization of BRICS stock market and increased its share in world financial market. Table 4 provides details about the BRICS stock market which helps to understand development level of the respective stock market.

Table 4. Overview of the BRICS stock market as of year 2016.

Country	Underlying stock market	Listed domestic Companies	Stock market capitalization	
			current US$, Billions	% of GDP
Brazil	Brazilian Stock Exchange (BM&FBOVESPA)	338	759	42
Russia	Moscow Exchange (MICEX-RTS)	242	622	48
India	National Stock Exchange (NSE)	1,839	1,540	69
	Bombay Stock Exchange (BSE)	5,820	1,567	
China	Shanghai Stock Exchange (SSE)	1,182	4,099	65
	Shenzhen Stock Exchange (SZSE)	1,870	3,213	
S. Africa	Johannesburg Stock Exchange (FTSE/JSE)	303	951	323

Source: The World Bank and World federation of exchanges.

The development level and size of stock market can be measured in several ways and stock market capitalization is one of the most commonly used indicators to know the development level of stock markets across various countries. The value of stock market capitalization is the share price times the number of shares outstanding for listed domestic companies which is also considered as a market value and of the company. In the last 20 years, the stock market of BRICS has increased its share in international market and has played significant role in growth of the global economy. The stock market of BRICS grew from US$1.2 trillion to US$6.4 trillion during the period of 2000 to 2010(Ministry of Finance, Government of India, 2012). The world stock market capitalization is about 64.85 trillion USD in 2016 (The World Bank, 2017) and the BRICS accounts for more than 16 percent of world stock market capitalization with USD$ 11.99 trillion (The World Federation of Exchanges, 2017). The stock market of China principally

includes the Shenzhen stock exchange which is significantly dominated by state owned enterprises (SOEs) and the Shanghai stock exchange which is not fully opened to foreign investors. China holds about 11 percent of the global stock market and stands out as a leader in terms of market capitalization among rest of the BRICS economies.

Similarly, the share of stock market capitalization in GDP is another indicator that measures the development level of stock markets and used to know the depth of stock markets. The size of stock market as a proportion of GDP in the BRICS economies has significantly increased in past 20 years' time. The market capitalization to GDP ratio of Brazil in 2000 was 34.5 percent and reached up to 98 percent during global financial crises in 2007 as it is 42 percent in 2016. In 2007, the ratio of China and India was 126 and 151.5 percent respectively which got shrink after the crisis and became 65 percent and 69 percent in 2016. Russia's stock market is 48 percent of GDP in 2016 which was 18.7 percent during the Russian financial crisis in 2014. The stock market of South Africa is larger than country's total GDP size among the BRICS since the origin days of BRICS. In 2000, South Africa's stock market was 149 percent of GDP which increased to 323 percent in year 2016 as it was reduced to 168 during 2008 after reaching 276 percent in year 2007. As most of the African countries tend to have small number of listed domestic firms in the respective stock markets, the number of listed firms in South Africa is less compared to the size of stock market in terms of market capitalization. However, the financial system and stock market of South Africa is considered as one of the most liberal one among other emerging market economies (Flavin &O'Connor, 2010). The stock market of China is considered as less competitive and has lower number of listed domestic firms as compared to the US that has the has the largest number of domestic firms after India. The number of listed companies in stock market of Brazil and South Africa has fluctuated and decreased as compared to rest of the BRICS nations in the last twenty years. In 2000, Brazil and South Africa has 457 and 604, but the number reduced to 338 and 303 respectively in 2016. The number of listed companies in Russia was on a rising trend but has fluctuated and reduced in recent years as China and India has continuously increased the number of listed domestic companies during the same period. The number of companies reached up to 817 in 2011 from 21 in 2000. The Moscow Exchange was founded after merger of the two largest Moscow based exchanges, the Moscow Interbank

Currency Exchange (MICEX) and the Russian Trading System (RTS) in 2011. Since the merger year, the number of listed companies has gradually decreased to 242 in 2016.

Over the last few years, the increasing level of integration with rest of the global economies and the performance of stock market during the financial crisis makes BRICS as an influential economic group in the global economy. Table 5 helps to understand further depth of respective stock market that includes year-end price weighted broad stock market indexes obtained from world federation of exchanges, value of shares traded as a percentage of GDP and turnover ratios of the respective stock market.

Table 5. Facts about the BRICS stock markets.

	Broad stock market indexes			Stocks traded, total value (% of GDP)	Stocks traded, turnover ratio (%)
	2016 Year-end	2015 Year-end	% change end 2016/2015	2016	2016
Brazil	60,227	43,350	38.9%	31.2	73.6
Russia	1,570	1,244	26.2%	10.9	25.7
India	18,019	17,359	3.8%	35.0	50.6
China	5,073	5,848	-13.5%	163.4	249.9
S Africa	50,654	50,694	-0.1%	136.5	38.4

Source: The World Bank and Global Financial Development Database.

Stock market index helps to measure the performance and know movement of the stock market. Table 5 provides details about the broad stock market indexes of BRICS nations as of year 2015 and year 2016. It includes price return index for Ibovespa index of Brazil, S&P BSE all Cap index and Nifty 500 of India for BSE and NSE, SSE and SZSE composite index for China, Moscow Exchange Broad Market Index for Russia and FTSE/JSE index for South Africa. Although the data excludes blue chip indexes which includes micro-cap stocks, broad market indexes is mostly used index to know the movements of the entire stock market as it includes securities with reasonable size and liquidity. Brazil and Russia have relatively high index in 2016 as compared to 2015 that results in increased and positive change in the respective index, whereas China has negative change of 13.5 percent with decreased index in year 2016. The value of shares traded as a percentage of gross domestic product is a total value traded ratio that captures trade value relative to the size of the economy. The value of shares traded as proportion

of GDP in South Africa and China are relatively higher as compared to rest of the BRICS economies. China has a high value of shares traded as a proportion of GDP than any country in 2016 with 163 percent. South Africa's stock market is 136.5 percent of GDP and it is bigger than Brazil with 31 percent, Russia with about 11 percent and India with 35 percent in 2016.Likewise, another measure to know the depth of stock market is turnover ratio which measures trading relative to the size of stock market. It is obtained as the total value of shares traded divided by average market capitalization for the period. In practice, the turnover ratio proxies the liquidity of the market and high turnover is an indicator of low transaction costs (Adu, Alagidede & Karimu, 2015). The stock turnover ratio of the BRICS market has considerably deepened over the last 20 year time. The turnover ratio of Brazil reached up to 96 percent in 2008 from 41 percent in 2000 and in 2016 the ratio is 73 percent. Similarly, the turnover ratio of India decreased to 50.6 percent in 2016 from a turnover of 143 percent in 2008. South Africa also posted a high turnover with 42 percent in 2008 as compared to 34 percent in 2000 and the ratio is 38 percent in 2016. The ratio in China jumped from 101.2 percent to 219.5 in 2008 and China is considered as the most liquid market among the BRICS stock market which has 249.9 percent of turnover in 2016 as compared to rest of the market followed by Brazil and India. There was significant amount of decline in the turnover ratio of all the BRICS nations in 2010 with exception to China which had 205 percent during that period.

2.3. Overview of the US economy and stock market

As I mentioned earlier about the shift of economic power in wake of the Cold War, the emergence of new economies during the post-cold war period has posed challenges to leader of the world trade and the global economy. China has been primarily able to attract investments from the US and rest of the world as it holds competitive advantage for low-waged labor, particularly in the production sector. India is considered as one of the largest economy and provides large volume of skilled based tradable services primarily in information technology, software development, engineering and pharmaceuticals to the international market. However, the United States has always played dominant and fundamental role as the world leader with its economic engagement among rest of the global economy. The US dollar is the mostly used and

dominant currency in international markets for trade and financial transactions and significantly taken as reserve currency by all countries around the world. Similarly, the role of the US in the global economy increased gradually during the era of trade liberalization. The growth in share of the global trade, and contribution in technological advancements and developments in production as well as service sectors shows the level of impact that the US has on rest of the world economy. The United States share of global output and trade has increased as compared to the share of other major advanced and developed economies which has fluctuated and mostly declined despite the rise and increasing presence of emerging nations such as China and India in the global economy.

The US economy has always recovered and enjoyed sustainable growth regardless of challenges from several critical economic and financial situations like economic recession of 1980s, 2006-07 housing bubble or subsequent 2007-09 global financial crisis. Currently, the US is the world's single largest economy with an estimated nominal GDP of more than $18 trillion in 2016. It accounts for more than 22 percent of the global GDP (at 2015 current prices based GDP), 11 percent of the global trade, and 35 percent of the global stock market capitalization. The US dollar is considered as world's preeminent reserve currency and the most widely used currency in global trade and financial transactions. The significance of the role played by the US financial markets in the world economy, large portion of share in the world trade, and open capital markets have always made the US economy as a dominant force in the global economy and financial market.

In addition, the dominance of the US in the global economy goes beyond import-exports of goods and FDI inflows-outflows as the US financial markets are highly integrated with global markets and the US equity markets account for a significant portion of the global equity markets. The US bond and equity market is the largest stock market in the world. It is considered as the most liquid market and cross-border spillovers from the US equity markets are large and depend more on openness to the global economy than on the size of portfolio flows (Ehrmann, Fratzscher & Rigobon, 2011; Rose & Spiegel, 2011). The US economy is considered as arguably the most successful capitalist system in the world with its continual dominance in the global economy (Jorion & Goetzmann, 1999) and capital markets in the US is considered as the

backbone of capitalism and liberalized economy. The stock market of the US not just plays role of raising funds for companies and be a source of income for investors but also considered as crucial for formulation and implementation of government policy and promote economic growth. The US stock market is considered as the biggest one where thousands of domestic as well as international companies are listed and traded. Table 6 provides further details about the size of the US stock market, value of shares traded as a percentage of GDP, turnover ratio as a proxy for the liquidity of the market and number of listed domestic firms in two major American stock exchanges, the New York Stock Exchange (NYSE) and the NASDAQ exchange.

Table 6. Description of the US stock market.

		2000	2004	2008	2012	2016
Stock market capitalization	current US$, Billions	15,108	16,324	11,590	18,668	27,352
	% of GDP	146.9	133	78.7	115.6	147.3
Listed domestic companies		6,917	5,226	4,666	4,102	4,331
Stock traded, total value (% of GDP)		289.6	155.6	321	200.2	226.6
Stock traded, turnover ratio (%)		197.1	117.0	407.6	173.3	94.7

Source: The World Bank & World Federation of Exchanges

The NYSE of the US is the largest stock exchange in the world in terms of market capitalization. The major stock indices of NYSE are NYSE composite, S&P 500 and Dow Jones Industrial Average. Similarly, the NASDAQ stock exchange of the US is the second largest stock exchange in the world in terms of market capitalization after the NYSE with Nasdaq Composite as the major index. The market capitalization of domestic listed companies of the US stock market that includes both NYSE and NASDAQ have increased from US$ 15, 108 billion in 2000 to US$ 27, 352 billion in 2016. Although the number of listed domestic companies has declined from 6917 in 2000 to 4331, the reduced number of listed firms has not affected the size of the stock market. The value of listed firms is 147.3 percent of GDP in 2016. The value decreased to 78.7 percent in 2008 during the period of global financial crisis 2007-09 from 146.9 percent in 2000. The value of shares traded in the US stock market as a proportion of GDP is relatively consistent throughout the years as it is 226.6 percent in 2016 as compared to 289.6 in 2001 which was reduced to 155.6 percent in year 2004. The turnover ratio of stock traded which is considered as a proxy to know the liquidity of the market decreased to 94.7 percent in 2016 from 197.1 percent

in 2000. During the period of global financial crisis 2007-09, in year 2008 the turnover ratio jumped to 407.6 percent from 117 percent in 2004. The movements and changes in the US stock market always have impact on international financial markets and such movements have important implications for international investors. Moreover, the US market has always been prominent around every corner of the world and influential on performance of the global stock markets.

3. THEORETICAL FRAMEWORK

This chapter provides details about the theoretical framework subjected to my thesis. The theoretical background helps to understand the existing theories related to study of stock markets' behavior and the volatility transmission mechanism across the international stock markets. In section 3.1, I present a brief theoretical concept about stock market volatility and volatility spill over. Thereafter, I discuss about the efficient market theory and/or efficient market hypothesis (EMH) developed by Eugene F. Fama (1970). The discussion includes various research works and arguments related to the concept of the perfect market. Section 3.2 provides a literature review of previous studies on stock market and volatility transmission among stock markets.

3.1. Theoretical background

3.1.1. Stock market volatility and spillover

In modern financial market, the stock market of each country trade on their respective time zone. The difference in each market's own trading time justifies the regular phenomenon of price changes and transmission of volatility from one market to another stock market. The concept of efficient market says that the early release of information cannot influence any assets value. However, it's not only about release of the new information, but the announcement of acceleration in the flow of information which will change the value. The volatility of asset prices is directly related to the rate of flow of information in an arbitrage-free economy. It is necessary to see whether such announcement or release of any sorts of information influence the price of any securities, payoffs from such trading and make the investment more valuable or not (Ross, 1989). In addition, information plays crucial role in movements of the stock price and has an immediate impact on stock market. It means that news and information are considered as a potential source of market volatility (Ederington & Lee, 1993). Moreover, as the volatility of asset prices is directly related to the rate of flow of information and changes in volatility reveals the arrival of new information (Ross, 1989); it can have an immediate effect on assets value as

well. Therefore, it is important for all market participants including international investor, policymaker and researchers to understand the impact of such information and the rate of flow on stock price indices of developed as well as emerging markets (Bhuyan et al., 2016; Natarajan, et al., 2014).

Similarly, changes in prices of assets change the level of stock market volatility, and changes in volatility of market return are easily transferred from one stock exchange to another within short span of time which will have important effects on investment decision. It means that we cannot ignore the significance of information in stock market volatility and spillover of volatility from one market to another. The stock market is expected to fluctuate in response to the information and volatility is expected when market participants perform the trade in response to such information. Therefore, we can say that volatility is an inevitable market experience which reflects fundamentals, information and market expectations (Kalotychou & Staikouras, 2009:3-22).

Furthermore, the stock market volatility is taken as a common phenomenon in modern financial market. Kalotychou and Staikouras (2009) explain the importance of volatility in financial economics and argue that stock market volatility is not a bad thing. The impact of volatility in equilibrium prices and volatility that helps to forecast and assist in valuation of securities explains the importance of volatility in the field of financial economics. Stock market volatility is even considered as a basis for finding efficient price by traders and investors who analyze trends in volatility for their risk management and investment decisions. Moreover, volatility can be decomposed into its predictable and unpredictable components, where its predictable component is a function of past information available at a given point (Theodossiou & Lee, 1993). Likewise, volatility is associated with unpredictability, uncertainty and has implications for variance risk. The financial market participants view volatility as a symptom of market disruption and often consider it as a problem for functioning of the capital markets where securities are not priced fairly (Bala & Premaratne, 2004). The test on mean-volatility spillover effects across the international stock markets shows that volatility has been so closely synchronized across international stock markets that past returns of one market have greater

effect on current returns of other market and suggests that to some extent investors are able to predict the future course of prices (Natarajan et al., 2014).

Spillovers are changes in returns or volatilities of the stock market due to transmission of market specific information from other market (Fleming, Kirbyb & Ostdieka, 1998). Natarajan et al. (2014) defines volatility spillover as a transmission of volatility and transmission of mean returns as mean spillover. Volatility spillover can be observed as within the market and cross market volatility spillover. The one way causal relationship between past volatility shocks and current volatility within the same market is referred as own volatility spillover. Whereas, the cross-volatility spillover indicates the one way causal relationship between past volatility shocks and current volatility in another market (Theodossiou & Lee, 1993).

3.1.2. The efficient market theory

When we study about the correlations between stock markets, and the dependence level of stock market and its impact on return, we can find various relevant cocepts and theories such as asset pricing theory, arbitrage pricing theory, portfolio theory, EMH, volatility transmission, information spillover effect and behavioral finance. The concept of law of one price lays the foundation for asset pricing theory and arbitrage pricing theory to explain stock market correlation from asset pricing perspective; whereas, EMH helps to explain stock market reactions that says stock prices reflect all of the available information about stock markets and the transmission of information between different stock markets lead to the correlation between the stock markets (Fama, 1970).

Fama (1970) defines efficient market as the market which reflects all available information. He discusses the idea of market efficiency to explain the relationship between information and share prices in the stock market and states that all available information about stock markets is integrated in the stock price. This implies that publicly available information does not allow people to obtain abnormal returns as information are available at the same time to all and only certain person cannot beat the market. He believes that rapid spread of the information to the public results in immediate price adjustment. The theory states that a current market price

represents the fairly priced value of the stock and we cannot outperform the market with specific strategy such as selection of particular stock or trading in specific time frame. The investor can obtain higher returns than the rest in the market only when one is ready to take significant amount of risk (Shleifer, 2000).

Fama (1970) proposed various assumptions which are essential to hold the concept of efficient market. The efficient market theory relies on the perfect market assumptions. The primary assumptions mentioned by Fama in his study are as follows:

I) All investors have homogenous expectations.

II) There are no trading related transaction costs.

III) The information is costless and publicly available to all market participants.

Although the EMH states that these assumptions need to hold for market to be efficient and perfect, we can say that it is not possible to hold all assumptions all the time. It means that markets can be inefficient, and investors can evaluate the securities and trade with higher return as compared to the market. However, as we can find various kinds of information from the market, Fama (1970) describes the efficiency of market with three different versions based on the available information: weak form efficiency, semi-strong form efficiency and strong form efficiency. As my thesis paper analyzes the stock market of emerging markets, the understanding of these forms of market efficiency is important to know the functioning and efficiency of the emerging markets. The trade liberalization, regulatory reforms and subsequent increase of investment in international equity market indicates the importance of understanding the efficiency of these emerging markets.

The weak form of efficient market states that the information set is just historical prices and a market is considered as the weak one when current prices of security reflects all information available from historical prices. This implies that historical prices do not help to predict future prices movements and it is difficult to earn abnormal returns for any investor from those stocks

which are selected largely on the basis of past prices as we cannot find any under-valued or over-valued stocks. According to the EMH, such analysis of historical prices and past returns to predict returns is known as technical analysis. It states that such analysis is not worthwhile for any investor to earn abnormal returns, as prices do not hold any patterns and there is a random walk in stock return series which will not have any serial correlation. The random walk theory suggests that current market price of a given stock is independent and unrelated to previous price patterns and one cannot predict future market prices based on the past history of price behavior (Fama, 1965a). Fama (1965b) finds that stock prices follow random walks. He did not find any systematic evidence of profitability earned from technical trading strategies. However, Lo and MacKinlay (1988) argues that stock prices do not follow random walks and their result of volatility based specification test indicates that the random walk model is generally not consistent with the stochastic behavior of weekly returns especially for the smaller capitalization stocks.

The semi-strong form of market efficiency states that prices efficiently reflects all other information that is publicly available such as announcements of annual earnings, stock splits, new security issues, etc. (Fama, 1970). It means that current prices of any stock are integrated with all available and relevant information and stock is traded at fair value in the stock exchange. Therefore, investor cannot outperform the market based on such publicly available information as they neither can undervalue nor overvalue the traded stock.

The strong form test performed by Fama (1970) concerns with whether given investors or management groups have monopolistic access to any information relevant for price formation or not. The test evidence shows that access to inside information about prices is not relevant for any investor in the investment community to generate any abnormal returns than the market. In this form of efficiency, the EMH assumes that all available private information is fully reflected in price of the security and such inside information available to any market participants does not have any effect in movement of stock prices. The strong form of the EMH states that it is not possible to earn any excess profits based on insider's information as such information leaks out quickly and incorporates into prices (Shleifer, 2000).

Various studies on market efficiency and insider trading (Lorie & Niederhoffer, 1968; Jaffe, 1974) shows that corporate insiders can earn abnormal returns and earning of such profit is against the strong form of efficient market. However, result also suggests that market traders who are outsiders and merely imitate insider trades can also earn abnormal returns using publicly available insider trading data which is considered as a violation of semi strong form of market efficiency. Rozeff and Zaman (1988) refers the earning of outsider profit by imitating insider trades as the "insider trading anomaly". The findings of the study by Rozeff and Zaman (1988) opposed the idea about corporate insiders having the information which market does not have and study results suggest that even if they possess any inside information on a regular basis, they do cannot earn excess profits from stock trading primarily based on such information.

The efficient market theory states that we cannot predict a future price as prices fluctuates accordingly with the availability of new information. And studies on the EMH argue that prices do adjust in response to such new information and market can be considered as efficient to certain level. Fama (1998) study on long term return anomalies and behavioral finance suggests that market efficiency cannot be abandoned. He concludes that anomalies are just a chance results and the long-term return anomalies are fragile which tends to disappear with reasonable changes. Jensen (1978) states that there is no other proposition in financial economics which has more solid empirical evidence supporting it than the EMH. The survey by Malkiel (2003) discusses about the EMH criticism and examines the relationship between predictability and efficiency. The study concludes that stock markets are far more efficient than what some research findings argues. However, he could not deny the fact that efficient market hypotheses are frequently violated and financial markets are at least partially predictable.

The efficient market theory explains the relationship between information and security price in the stock market and states that markets are efficient. The concept of efficient markets has been criticized since its introduction days for its practical implication, as critics argues that in real world it is not possible to have efficient market. The behavior of some irrational investors along with the likelihood of information asymmetries and trading related transaction costs during the period of the global financial crisis of 2007-09 challenged the hypothesis of efficient market. The crisis proved that it is not necessary for all investor to behave in a rational way. Moreover, the

concept of market efficiency has been challenged during the crisis period as we saw that stock prices did not always explain the fundamental values. The dramatic movements in one stock market during the period of crisis always have a powerful impact on other markets of very different sizes and structures across the globe (Forbes & Rigobon, 2002). During the last few decades, we can see that how crises have been generated and transferred from one region to another region. The technological advancement and development in information and communication mechanism has made easier to access and transfer information from one region to another region resulting international markets to become more integrated than ever. Some critics even say that the EMH is just a theory and the global financial crisis proved that financial regulators had a mistaken belief about the concept of efficient market and the EMH. Despite being aware about the fact of consistent high returns reported by some financial institutions, financial regulators were unable to supervise the market and prevent the crisis (Ball, 2009). Stanley (2003) study on economic fluctuations discusses the concept of outliers (rare events, bubbles, crashes) and suggests that we cannot simply ignore them. He argues that traditional economic theory does not predict such outliers and criticize the EMH for theoretical ignorance of such extreme and devastating events that can occur at any time in financial markets.

Despite facing various criticisms, primarily for practical implications in the real world, the concept of efficient market has laid the foundation for several financial and economic theories and still considered as one of the prominent concept in finance. However, new theories have begun to emerge which provides an alternative view to study financial markets. Behavioral finance is one of the theories which see that systematic and significant deviations from efficiency are expected to persist for long duration and argues that such economic theory does not lead us to expect financial markets to be efficient (Shleifer, 2000).

3.2. Literature review

The research paper by Bhuyan, et al. (2016) on information transmission and spillover effects between the US stock market and the emerging stock markets claims to be the first study that focuses on all five emerging equity markets of the BRICS economies. The research looks into

stock price movements of the US market and the BRICS by studying the effects of return and volatility spillover from the US market to BRICS. The result of the study is based on GARCH framework model used for daily data during the period of 1999 to 2012 and suggest that the US stock market has significant mean return and volatility spillover effects on the BRICS stock markets. The paper recommends that South Africa might provide a better opportunity to potential investors who are looking higher risk-return trade-off than of the US stock market. Brazil and India can be considered as second option for such investors as compared to other BRICS nation. Similarly, the study by Sarwar and Bhuyan (2009) on four stock markets of the BRIC economies for the period of 1995 to 2007 uses the GARCH framework to analyze the transmission of information between the US and the BRIC stock markets. The result suggests that the US stock market has significant mean return and volatility spillover effects on the BRIC stock markets.

Along with the study by Bhuyan et al., (2016) and Sarwar & Bhuyan (2009), we can find numerous earlier studies on the dynamics of stock market return and volatility spillovers across stock market that explains the information transmission mechanism between the advanced and emerging stock markets. Theodossiou and Lee (1993) use the multivariate GARCH model to examine the magnitude and transmission mechanism of stock market returns and volatility spillover across stock markets of the US, Japan, the UK, Canada and Germany. The result suggests existence of strong time-varying conditional volatility in the return series of all markets and the US has volatility spillover effect on other markets. Similarly, Booth, Martikainen and Tse (1997) study the four Scandinavian stock markets (Denmark, Norway, Sweden and Finland) and investigate price and volatility spillover among these markets. The result suggests that linear dependence of each market's return and volatilities might be due to some form of market inefficiency as the market volatilities respond strongly to bad news (shocks) than good news with exception to Denmark. Beirne, Caporale, Ghattas and Spagnolo (2010) study forty-one different emerging markets from all around the world and use multivariate GARCH framework to capture global and regional spillovers in mean returns and volatility. The research results suggest that spillovers in mean return from global markets are present in most of the emerging nations. Similarly, the evidence of spillovers in variance is observed in some of the European markets.

Bala and Premaratne (2004) study on volatility spillover between the Singapore stock market and stock markets of the US, the UK, Hong Kong and Japan investigates volatility co-movement between these stock markets. The paper has employed various econometric models based on the GARCH framework. The use of Univariate GARCH, VAR and a Multivariate and Asymmetric Multivariate GARCH model for daily returns from 1992 to 2002 indicates that there is a high degree of volatility co-movement between Singapore and other stock markets. Likewise, Abbas, Khan and Shah (2013) employs bivariate GARCH model to examine the presence of transmission of volatility among the developed markets (the US, the UK, Singapore and Japan) and the emerging markets (Pakistan, China, India and Srilanka). The study analyses the nature of economic and political links among these countries. The study finds evidence of volatility transmission within the markets of these nations which indicates that political difference does not matter as long as they share trade and commercial links.

The research by Ng (2000) examines the nature of return and volatility spillovers in international stock market. The study investigates the regional (Japan) and world (the US) market factors influence on market return volatility of six Pacific–Basin markets (Hong Kong, South Korea, Malaysia, Singapore, Taiwan, and Thailand) and examines the fundamental forces driving the return volatility in the Pacific–Basin region. The paper employs the GARCH framework for the weekly returns of respective markets to investigate the sources of volatility for different markets in the Pacific–Basin region. The study analyses the level of impact on volatility of Pacific–Basin market caused by foreign shocks from other national markets. The study finds that world market factors are important for market volatility in the Pacific–Basin region than the regional market. It also finds that the comparative importance of both market factors is influenced by economic and financial liberalization, fluctuations in currency returns, and the size of trade. Whereas, Miyakoshi (2003) constructs the volatility spillover model and studies the nature of volatility spillovers from Japan and the US to seven Asian markets and result suggests that there is a vast influence from Japan on volatility of Asian markets than from the US which is different to the result of Ng (2000).

The stock market crash of 1987 is considered as one of the biggest financial turmoil in the last fifty years which have significant impact in the international financial market. King and

Wadhwani (1990) investigate the transmission of volatility to other market in context of the 1987 stock market crash. The paper tests the change in prices and correlations between the stock market of London, New York and Tokyo during the period of crash. They argue that along with the information about prices changes in one stock market, "mistake" from one market is also easily transmitted to another stock market. The study highlights the US stock market crash and investigates the transmission of crash to rest of the stock markets. The result shows rise in the correlation between markets just after the crash despite the existence of differences in economic circumstances across these nations.

Xu and Hamori (2012) examine the dynamic linkages between the BRIC stock markets and the US during the 2007-09 financial crisis by analyzing the daily closing stock price indexes. The study divides the entire sample period into pre-crisis and post-crisis periods to study impact of the crisis. It uses the cross-correlation function (CCF) approach to examine the relationships in mean and variance of stock prices. The study result suggests that the international transmission of stock prices between the BRIC and the United States significantly weakened in both the mean and variance after 2007–09 financial crisis. Similarly, the study by Kim, Kim and Lee (2015) analyzes the vulnerability of the US financial market and measure the role of foreign capital for the conditional correlations in international equity markets. The paper examines the spillover effects of the US financial crisis on five emerging Asian countries (Indonesia, Korea, Philippines, Thailand, and Taiwan) by using multivariate GARCH models. The study finds that the crisis has short-lived but non-negligible spillover effect on emerging Asian countries.

Rejeb and Arfaoui (2016) looks at the structure of interdependence between stock markets of the emerging nations (Asian and Latin American countries) and the developed ones (the US and Japan) by studying volatility spillovers during the period of 1993 to 2010. The paper aims at study of international markets interdependence in terms of volatility transmission and the contagion effects occurred during the global financial crisis 2007-09. The paper uses standard GARCH model and quantile regression approach for MSCI market return indices of both emerging and the developed markets. The study finds the existence of volatility transmission between emerging markets as well as between emerging and developed markets. Likewise, Rejeb and Boughrara (2015) study the interdependencies among the emerging markets (Argentina,

Brazil, Chile, South Korea, India, Mexico, Thailand) and the developed markets (the US and Japan) by examining the volatility relationships during the normal and the crises period. The paper employed the VAR methodology with GARCH (1, 1) model on monthly returns to assess the impact of financial liberalization on these interdependencies during the period from 1976 to 2008. The study finds the presence of volatility spillover in international markets and shows that the international transmission of volatility has been intensified significantly by the implementation of financial liberalization. The findings also proved that financial shock transmit from one market to another during financial crises and geographical proximity plays a significant role in amplifying such volatility transmission.

The study on the background of the global financial crisis 2007-09 to understand the information transmission and dynamics of stock price movements among the US, the BRICS and the European markets suggest that financial crisis 2007-09 has changed the correlations between developed and the emerging stock markets (Aloui, et al., 2011; Zhang, et al., 2013). Aloui, et al. (2011) examine the time-varying dependence level and analyze the cross-market correlations to find the impact of financial crisis among the BRIC markets and the US. The paper uses multivariate copula approach for the daily returns of stock market indices during the period of 2004 to 2009. The result suggests that dependency on the US is higher and more constant for Brazil and Russia than for China and India. Similarly, the study by Zhang, et al. (2013) analyze the impact of the financial crisis on conditional correlation and employ the dynamic conditional correlation (DCC) model to generate correlation series between the BRICS and developed markets. The study finds similar results as of Aloui et al. (2011) as Brazil and Russia's stock markets have stronger correlations with developed countries than that of India and China. Although the result shows immediate increase in the correlation between China and developed markets after the 2007-09 crisis, the correlation between China and US is still low after the crisis. In context of the global financial crisis 2007-09 and subsequent EU debt crisis, Bekiros (2014) analyze the nature of volatility spillovers by examining linear and nonlinear causal relationships among the US, EU and the BRIC markets. The paper uses multivariate GARCH specifications to capture the short-run movements and the volatility spillover mechanism for daily stock index returns with an assumption that spillovers are realizations of international news that affects the

global stock markets. The result shows that BRIC have become more internationally integrated after the US financial crisis and the subsequent European debt crisis.

Bhar and Nikolova (2007; 2009) analyze the level of integration among the BRIC countries within its region and the world. The paper by Bhar and Nikolova (2007) measures the level of integration and effects of the mean stock return and volatility spillover from regional and the world indices on the BRIC markets. The paper use two-stage GARCH-in-mean approach (GARCH-M) to estimate the equation for daily closing stock market indices during the period of 1995 to 2004. The results implied that the US stock market influences the variance of returns for Brazil, Russia and India. The result shows that the effects from the world market are positive for all BRIC countries in terms of mean spillover, whereas in terms of the volatility spillover, the effects are positive for Brazil, Russia and India but negatively significant for China. Similarly, the study by Bhar and Nikolova (2009) employs the bivariate EGARCH structure to find the level of integration of BRIC nations with the world market in the post-liberalization period. They argue that the use of bivariate EGARCH model allows for time-varying conditional correlation of index equity returns from the respective stock markets. The paper suggests that the DCC aspect of the model allows to observe the impact of significant events in the BRIC markets on the correlation of index equity returns with their respective regions and the world market. The research paper uses weekly data set for period of 1995 to 2006 and result shows that India has the highest level of integration on a regional basis and the world market, followed by Brazil and Russia and China.

The research paper by Natarajan, et al. (2014) examines the nature and magnitude of the mean and the volatility spillovers in the stock markets of Australia, Germany, Brazil, Hong Kong and the US. The paper analyzes the inter-market volatility by adopting the GARCH model to find the direction and extend of mean spillovers and volatility spillovers across these five stock markets for the period of 2001 to 2011. However, the study finds existence of stationary and ARCH effects in the return series of Brazil and Hong Kong and these two countries are excluded for final analysis. The study finds the presence of significant negative own-spillovers and cross volatility spillover among the rest three stock markets. The result shows that current volatility of the Australian and German market is influenced with varying degrees of intensity by the past-

market volatility shocks in the USA. The results suggest that the study on information transmission and spillovers of returns across markets help to get some practical implications for diversification of international portfolio and risk management.

Syriopoulos, Makram and Boubaker (2015) use the GARCH framework to look into the dynamic risk return properties of the BRICS and the US stock market. The study focuses on understanding of business, industrial and financial sectors and examines the sector based return sensitivity and volatility spillover effects generated by the 2007-09 global financial crisis. The VAR-GARCH model is employed for daily data series that covers the period of 2005 to 2013. The model is used to find spillover effects in both conditional returns and conditional volatilities and capture the impact of any critical shocks or news from the US on the BRICS economy. The result presents evidence of shock and volatility spillovers between the US and BRICS markets. The finding of the study is similar to Mensi, et al. (2014) which suggest that past own volatility is a critical factor to determine the future volatility. The result shows presence of significant return and volatility transmission dynamics between the US and the BRICS stock markets.

Mensi, Hammoudeh, Nguyen and Kang (2016) conducts research on the backdrop of 2007-09 financial crisis to provide insight into the spillover effects among the US and the BRICS stock markets during the pre-crisis and the post-crisis period. The paper employs the multivariate DCC Fractionally Integrated Asymmetric Power ARCH (DCC-FIAPARCH) model to capture the volatility spillovers between the US and the BRICS stock markets. The paper estimates the model by using daily spot indices of the markets over the period of 1997 to 2013 to examine the dynamic linkages of the BRICS stock markets with the US. The result shows that there is a significant dynamic correlation between the US and the BRICS stock markets with Russia as an exception. The paper by Mensi, Hammoudeh and Kang (2017) also study the BRICS markets on the same issue of spillover as studied on previous paper. However, along with the US, the paper examines spillovers effects between the BRICS and other developed stock markets (Japan, Europe and Asia-Pacific region) by using Dynamic Conditional Correlation Fractionally Integrated Exponential GARCH (DECO-FIEGARCH) model for daily stock indices during the period of 1998 to 2016. They argue that the model helps to analyze the changes in the correlations during the financial stability as well as crisis periods. The analysis considers various

facts of stock return series such as volatility persistence, long memory and asymmetry in volatilities of the equity market. The study finds a significant variability in the time-varying conditional correlations between the developed and BRICS markets from early 2007 to mid-2008 for both upward and downturn phase of the market. The result suggests that investment in the BRICS market offers a positive returns and portfolio protection during market downturn and stress periods.

4. RESEARCH DATA AND METHODOLOGY

This section of my thesis provides details about the data used for analysis of the volatility transformation and the spill over effect. Section 4.1 includes details about the data and summary of statistics for weekly data of stock market returns obtained from the Morgan Stanley Capital International (MSCI) index. Section 4.2 illustrates the research methodology used for econometric analysis of the data.

4.1. Data and descriptive statistics

My thesis data on stock market return consist of the MSCI country index for the US and stock market of the five BRICS nations (country wise index). I have obtained weekly data from the MSCI for the period of 2000 to 2016. The reason behind selection of weekly data is to have high number of observations by avoiding any sorts of possible biases which might occur in the use of daily data such as differences in trading hours, non-synchronous trading days and national holidays that will make one stock market open and the other close (Martens & Poon, 2001; Lahrech & Sylwester, 2011; Arouri, Jouini & Nguyen, 2012; Lin, Wesseh & Appiah, 2014; Noor & Dutta, 2017).

The data obtained from the MSCI index covers a sample size of 887 observations and data are measured in the US dollar. The research evidence implies that stock market volatility dominates the exchange rate volatility and shows that there is little difference in results compared to use of returns in local currency units. This suggests that exchange rate fluctuations do not matter so much in the US and local market equity correlations. However, measurement in the US dollar helps to compare across countries as transformation implicitly captures impact of exchange rate movements in returns and it is also relevant for global investors (Lahrech & Sylwester, 2011; Mun, 2007). The weekly returns measured in U S dollar are calculated as below and calculation of the returns in the US dollar eliminates the local inflation (Bekaert & Harvey, 1995):

$$r_{t=} In\left({P_t}/{P_{t-1}}\right) X100$$

The calculation gives the value for natural logarithmic value of the weekly price indices, where r_t is the index return at trading time t and P_t and P_{t-1} are closing prices of an index at time 1 and t-1 respectively.

The summary of statistics for weekly data on returns of the US and BRICS stock market are presented in table 7. I have divided the data sample into full period from January 2000 to December 2016 and three different sub-periods[1&2]: January 2000 to June 2007 as pre-crisis period, July 2007 to June 2009 as the crisis period and July 2009 to December 2016 as post crisis period. The descriptive statistics table provide details about the name of stock market, sample period based total number of observations, the mean which provide details about the average weekly return of the stock market index, median value, minimum and maximum return value for each market and the standard deviation that represents level of risk and measures the volatility of market returns for full period and three different sub-periods. The average weekly return of the BRICS index is positive and higher than the return of the US index (0.0458) for the full sample period and other periods as well. During the crisis period, most of the BRICS market index experienced sharp decline and negative returns with high level of risk compared to the pre-crisis and the post-crisis periods. The level of risk measured by standard deviation of the US index is lower than the BRICS nations for all of the sample periods. The result also shows the lowest maximum values of the returns (11.5261) for the US index. The four BRICS nations exhibit more extreme negative values than the US, with South Africa as exception with less negative values for all of the sample periods. The result exhibits that the BRICS as emerging markets generate high average returns than the US market with higher risk and appear to be more volatile (measured by standard deviation). However, the result also shows increased average weekly returns in the US market after the crisis period. The weekly return series of all markets for all sample periods are skewed negatively with exception to positive skewness for Russia (0.5869) and South Africa (0.6602) in the crisis period. The positive skewness indicates a long right fat tail (extreme gains) and negative skewness suggest that the series have a longer left tail which means the probability of large decline in returns or having extreme losses. The kurtosis statistic is positive and high for most of the return series. This suggests that returns are not normally distributed, return series distribution is leptokurtic and has more weight in the tails i.e., distribution are fat tailed, and shows possibility of the market to earn extreme values of returns.

Table 7. Descriptive statistics.

	Brazil	Russia	India	China	South Africa	US
Panel A: Full Period						
Mean	0.0772	0.1651	0.1669	0.0585	0.1839	0.0458
Median	0.3907	0.3400	0.4593	0.3194	0.2940	0.1775
Maximum	25.6173	44.9165	13.6598	17.7590	16.2635	11.5261
Minimum	-33.0558	-27.7974	-18.9998	-22.2789	-10.8045	-20.1161
Std. Dev.	5.2104	5.0778	3.3683	3.9526	2.7647	2.5001
Skewness	-0.5272	-0.0428	-0.5807	-0.4601	-0.0451	-0.8371
Kurtosis	7.5841	13.0626	6.2265	5.6127	5.5100	10.0670
Jarque-Bera	817.74[a]	3742.53[a]	434.58[a]	283.58[a]	233.15[a]	1949.36[a]
Observations	887	887	887	887	887	887
Panel B: Pre-crisis Period						
Mean	0.3121	0.4189	0.2517	0.1515	0.2621	0.0004
Median	0.7276	0.5352	0.6552	0.3997	0.5129	0.1152
Maximum	13.3399	17.3469	13.3349	10.0126	9.2171	7.5744
Minimum	-19.9024	-22.9404	-14.7124	-16.0537	-10.8045	-12.3078
Std. Dev.	4.9169	5.1578	3.4875	3.9910	2.8483	2.2943
Skewness	-0.7302	-0.5317	-0.7964	-0.7588	-0.4993	-0.6291
Kurtosis	4.7461	4.9892	5.6841	4.4987	4.1771	6.8224
Jarque-Bera	84.43[a]	82.89[a]	158.70[a]	74.12[a]	38.82[a]	263.83[a]
Observations	391	391	391	391	391	391
Panel C: Crisis period						
Mean	-0.1018	-0.7587	-0.1178	-0.0293	-0.1381	-0.4666
Median	0.1702	-0.0944	0.5474	0.6838	0.0902	-0.2321
Maximum	25.6173	44.9165	17.7590	13.6598	16.2635	11.5261
Minimum	-33.0558	-27.7974	-22.2789	-18.9998	-9.6951	20.1161
Std. Dev.	8.5620	8.8675	6.3845	5.4533	4.1218	4.1906
Skewness	-0.5222	0.5869	-0.2086	-0.3202	0.6602	-0.6993
Kurtosis	5.8392	9.8717	3.8231	3.6959	5.2192	7.3061
Jarque-Bera	39.66[a]	210.59[a]	3.69	3.88	28.90[a]	88.83[a]
Observations	104	104	104	104	104	104
Panel D: Post-crisis period						
Mean	-0.1097	0.0124	0.1344	0.1571	0.1914	0.2271
Median	0.1450	0.1350	0.2189	0.2845	0.2150	0.2992
Maximum	22.5708	12.6607	9.3441	11.6709	6.5937	7.1395
Minimum	-15.4201	-12.0301	-9.9510	-13.2274	-6.8306	-7.6358
Std. Dev.	4.2418	2.9592	2.3926	3.2994	2.1724	2.0449
Skewness	0.0912	0.0152	-0.0659	-0.2683	-0.0446	-0.3488
Kurtosis	5.3098	4.0913	3.7620	4.8400	3.5227	4.5384
Jarque-Bera	87.69[a]	19.47[a]	9.76[a]	60.00[a]	4.59[c]	46.61[a]
Observations	392	392	392	392	392	392

a, b and c indicates statistical significance at 1%, 5% and 10% levels respectively.

The Jarque-Bera (JB) test is done to measure the normality of stock returns based on the value of skewness and kurtosis to see whether the series are normally distributed or not. The JB statistics in the table shows high level of significance and rejects the null hypothesis of normality for all return series (India and China as the exception for crisis period).

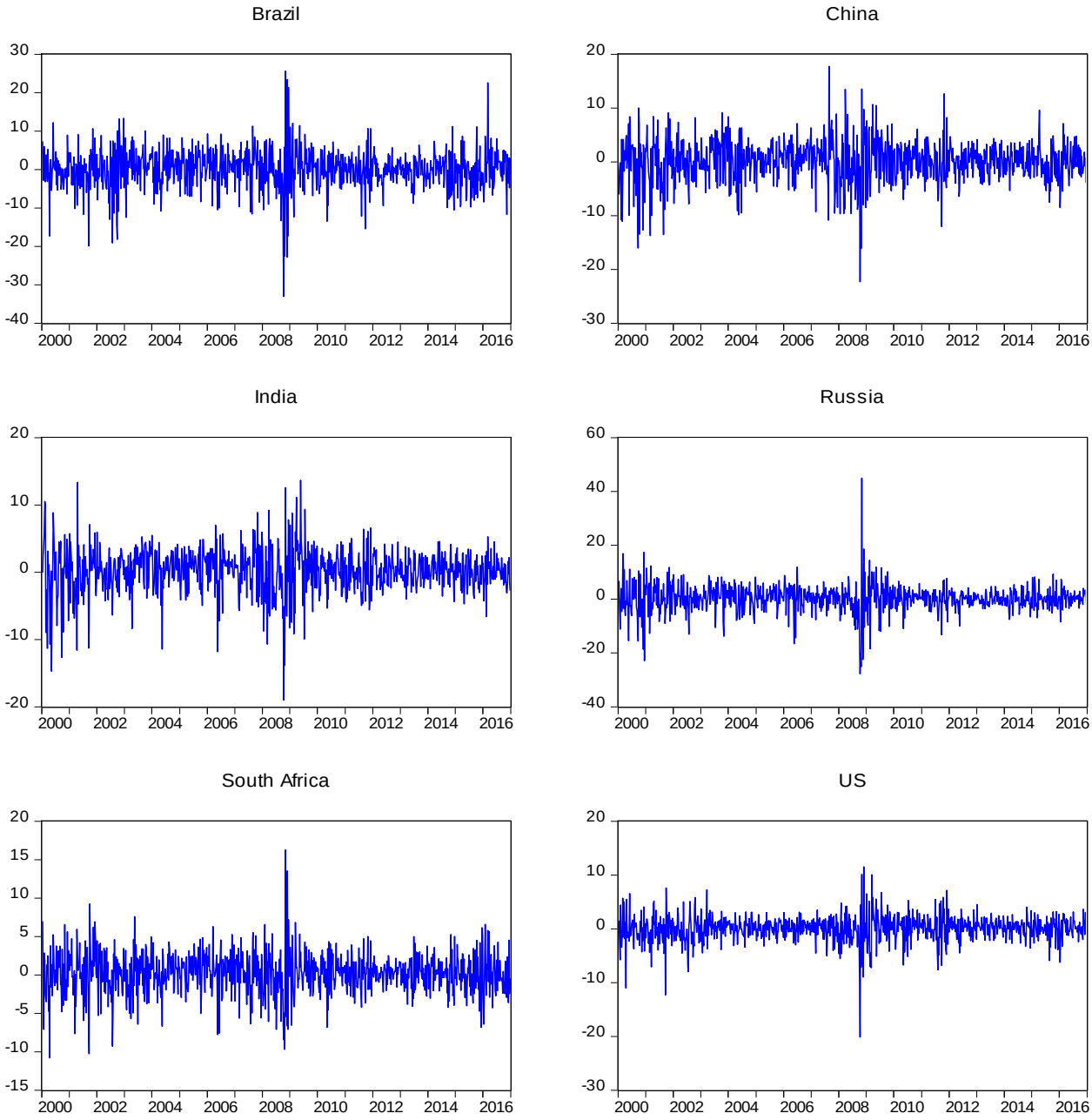

Figure 3. Weekly stock market return for the BRICS and the US.

Moreover, figure 3 illustrate the return series of respective country's market indices and indicates the existence of volatility clustering behaviour in the series. In most of the research work where high frequency data for stock prices are employed, a pattern of fluctuation is observed. The pattern of fluctuations suggests the existence of frequent ups and down across time periods with cycle of low and high volatility which is known as volatility clustering. This is viewed as a common phenomenon in financial time series which suggest that stock markets have period of high as well as low volatility (Abbas et al., 2013). Isakov and Perignon (2001) describe volatility clustering as one of the features of Instantaneous Volatility. They define volatility clustering as the presence of autocorrelation in volatility, which means that a day of high (or low) volatility is very likely to be followed by a day of high (or low) volatility. The presence of volatility clustering behaviour suggests that the GARCH model is appropriate for modelling the volatility of the return series. I have discussed further about the GARCH framework and its implications for international transmission of stock returns and volatility in next section.

Table 8 presents the correlation matrix for the full sample period. The result basically shows that all series are positively correlated with each other. Results in correlation matrix obtained from correlation test might not fully capture the dynamic linkages in a reliable way (Bekiros, 2014). However, we observe the significant cross-correlations with the US for all of the BRICS market and Brazil have the highest correlation with the US (0.6121). The result suggests similar conclusion of Lahrech and Sylwester (2011) who found that most of the Latin American countries have positive correlation with the US stock return due to high trade share and Brazil's large size of trade share with the US could be the one reason for such high correlation.

Table 8. Result of correlations matrix.

	Brazil	China	India	Russia	South Africa	US
Brazil	1					
China	0.4977	1				
India	0.4562	0.5254	1			
Russia	0.5670	0.4151	0.4045	1		
South Africa	0.5507	0.4720	0.4710	0.5313	1	
USA	0.6121	0.4693	0.4395	0.4986	0.5655	1

Table 9 presents the results for Augmented Dickey and Fuller (ADF) and Phillips and Perron (PP) tests to check the stationarity conditions of the return indices. The null hypothesis for the ADF and PP test states that return series have a unit root and data are non-stationary. The ADF test result rejects the null hypothesis of a series at 1% significance level and we need to accept the alternative hypothesis as the p value is lower than the significance level. It means that there is no unit root for the series and the test result confirms that the first difference of all individual return series is stationary. The stationarity condition of the data helps us to employ auto progressive process when we model the return series (Noor & Dutta, 2017).

Table 9. Unit test results of weekly return indices.

	ADF Tests		PP Tests	
	1st Difference		1st Difference	
Brazil	-12,97	(0.00)***	-215,85	(0.00)***
Russia	-11,71	(0.00)***	-218,62	(0.00)***
India	-11,51	(0.00)***	-440,27	(0.00)***
China	-11,38	(0.00)***	-528,85	(0.00)***
South Africa	-11,18	(0.00)***	-205,42	(0.00)***
US	-12,17	(0.00)***	-207,34	(0.00)***

Notes: The table presents results of ADF and PP tests to check the stationarity conditions of the return indices for full data sample period. *** indicates statistical significance at 1% level. The values in parentheses indicate p values.

4.2. Econometric methodology

The main objective of my thesis paper is to study the volatility spillover, the transformation process and its impact from one stock market to anoher. Therefore, in this section I have analyze the VAR-GARCH framework as an econometric method employed for the sample data to study the volatility transmission mechanism and spill over effect from the US to the BRICS stock market.

The ARCH model and the GARCH framework initially proposed and introduced by Engle (1982) and subsequently discussed and developed by Bollerslev (1986) are the regularly used econometric processes used for modeling time series with leptokurtic observations where the

volatility of return series are clustered (He & Teräsvirta, 1999). The ARCH framework as a new stochastic process was first introduced by Engle (1982) in his study to estimate the mean and conditional variance of inflation in the UK. The work of modeling conditional variance of financial time series by Engle was discussed and extended later by Bollerslev (1986). Bollerslev (1986) generalized the ARCH process introduced by Engle (1982) and proposed the GARCH model allowing for much more flexible lag structure. The ARCH process recognizes the difference between the unconditional variances and conditional variances allowing the conditional variances to change over time as a function of past errors. The GARCH model as an extension to the ARCH process suggests that conditional variance depends on past values of squared returns as well as past value of the variance (Bouri, 2015).

Over the time-period, number of research work has been done to examine the volatility transmission mechanism between stock market indices and the GARCH framework has been the most employed method by numeruous papers for modelling of conditional variances of such financial time series. In general, the GARCH models are employed to explore the stochastic behavior of financial time series and explain the behavior of stock market volatility (Theodossiou & Lee, 1993; Bollerslev, Chou & Kroner, 1992). We can find univariate as well as multivariate specifications for the modelling purpose. However, the use of multivariate GARCH model has various advantages over univariate. A multivariate GARCH model avoids the problems associated with estimated regressors (Koutmos & Booth, 1995) and helps to capture the dynamic relationship between stock markets by improving the efficiency of spillover test. The use of multivariate GARCH model with dynamic co-variances and conditional correlation is considered as methodologically consistent model with the notion that volatility spillovers are manifestations of the impact of global shocks on any given market (Bala & Premaratne, 2004). The most popular and commonly used GARCH models with multivariate specifications to investigate volatility transmission mechanism in different time series are CCC (Constant Conditional Correlation) model, BEKK (Baba-Engle-Kraft-Kroner) and DCC (Dynamic Conditional Correlation) model. The research paper by Theodossiou and Lee (1993), Bhar and Nikolova (2007;2009), Beirne et al. (2010), Bekiros (2014), Zhang et al. (2013), Mensi et al. (2016) has employed various multivariate GARCH specifications to examine the magnitude and transmission mechanism of stock market returns and the volatility spillover across stock markets.

However, various studies on volatility transmission argue that the above mentioned specifications have some problems in modeling financial volatility. Hammoudeh, Yuan and McAleer (2009) highlight the problem of BEKK model which is typically not attached to VAR (1) model. The problem of convergence during the estimation process, having too many parameters and computational complications with lack of empirical explanations (Arouri et al., 2011; Lin et al., 2014; Bouri, 2015) of the above discussed models give VAR-GARCH as an alternative model proposed by Ling and McAleer (2003). The study by Arouri et al. (2012) and Lin et al. (2014) discuss further about the advantages of use of the VAR-GARCH model that allow for cross market volatility transmission effects. Similarly, Bhuyan et al. (2016) used quasi-maximum likelihood estimation (QMLE) procedures under the GARCH framework to find out the spillover effects between the US and the BRICS stock markets. The study even compares the result of EGARCH model with the GARCH model and state that GARCH (1, 1) framework produces consistent and better estimates than EGARCH. Therefore, I have used the VAR-GARCH model which permits a multivariate analysis of conditional volatility of the return series as well as volatility spillovers between series. It will help to avoid any computational complications and provides meaningful estimates with less parameter which will help to focus on estimation of meaningful and interpretable parameters. Moreover, with presence of the ARCH effect in the return series, the GARCH (1, 1) specification model is considered as the most fitting one to predict volatility (Bollerslev, Engle & Nelson, 1994).

I have applied a bivariate VAR (1)-GARCH (1, 1) framework to model the dynamics of BRICS and the US stock market and estimate the regression equations. I have followed the similar approach used by Noor and Dutta (2017) and Syriopoulos et al. (2015) to model my data and investigate market shocks, volatility dynamics and spillover effects between stock market of the US and the BRICS. The bivariate VAR-GARCH models the mean and variance equation of each stock market respectively and in VAR (k)–GARCH (p, q) model, k refers to number of lags in the VAR model, and p and q represents ARCH and GARCH effects, respectively. The US capital market is considered as the dominant and assumed to impact the global capital market. Therefore, it is expected that the use of VAR-GARCH model will help to depict the dynamic US-BRICS stock market interaction induced by shocks, events or news (Syriopoulos et al., 2015). The VAR (1)-GARCH (1, 1) specification is preferred on the basis of the Akaike (AIC)

and Bayesian (BIC) information criteria after performing unit root test for stationarity of data. The optimal number of lags for the models is selected based on the AIC and BIC criteria. The conditional mean equation of VAR (1)-GARCH (1, 1) specification that presents the returns of the US stock market and the BRICS stock market can be modeled as below:

$$R_t = \mathrm{C}_i + \theta R_{t-1} + \epsilon_t \qquad (1)$$

$$\epsilon_t = D_t^{1/2} \eta \mathrm{t} \qquad (2)$$

The equation 1 can be further illustrate and explained as below:

$$\begin{bmatrix} R_{1,t} \\ R_{2,t} \end{bmatrix} = \begin{bmatrix} C_1 \\ C_2 \end{bmatrix} + \begin{bmatrix} \theta_{11} & \theta_{12} \\ \theta_{21} & \theta_{22} \end{bmatrix} \begin{bmatrix} R_{1,t-1} \\ R_{2,t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \end{bmatrix} \qquad (1.1)$$

In equation 1, R_t refers to 2 x 1 vectors of weekly returns at time t of the BRICS stock index and the US index respectively. It means $R_t = (r_t^{BRICS}, r_t^{US})/$, where r_t^{BRICS} and r_t^{US} are the returns of the BRICS and US stock market index at time t respectively.

C_i refers to 2 x 1 vectors for the constant term (as i = 1, 2).

$\theta = \begin{pmatrix} \theta_{11} & \theta_{12} \\ \theta_{21} & \theta_{22} \end{pmatrix}$, and refers to a 2x2 matrix of coefficients. It is the matrix of parameters of the vector autoregressive term and measures the impact of own market lagged mean transmission and cross market mean spillover between the BRICS and the US stock market. This structure helps to measure the effects of innovations (shocks) in the mean stock returns of one series on its own lagged returns and those of the lagged returns of the other market (Syriopoulos et al., 2015). ε_t is the 2 x 1 vector of the residual terms for the conditional mean equation of the BRICS and the US stock market returns at time t. It means $\varepsilon_t = (\varepsilon_t^{BRICS}, \varepsilon_t^{US})/$ where ε_t^{BRICS} and ε_t^{US} are the residual terms of the mean equation for the BRICS and the US stock market returns respectively.

In equation 2, $D_t^{1/2} = diag\sqrt{h_t{}^{BRICS}}, \sqrt{h_t{}^{US}}$ where the terms h_t^{BRICS} and h_t^{US} represents the conditional variances of the BRICS and the US stock market returns (i.e., r_t^{BRICS} and r_t^{US}) respectively. The equation 3 and 4 models and defines the conditional variance and volatility transmissions over time across the BRICS and the US stock markets respectively.

Similarly, $\eta_t = (\eta_t^{BRICS}, \eta_t^{US})'$ and refers to a2 x 1 vector of the innovation term (shock) and a sequence of the independently and identically distributed random process (errors).

$$h_t^{BRICS} = c^2{}_{BRICS} + \beta^2{}_{BRICS,t}\left(h_{t-1}^{BRICS}\right) + \alpha^2{}_{BRICS,t}(\epsilon_{BRICS,t-1}^2) + \beta^2{}_{US,t}\left(h_{t-1}^{US}\right) + \alpha^2{}_{US,t}(\epsilon_{US,t-1}^2) \quad (3)$$

$$h_t^{US} = c^2{}_{US} + \beta^2{}_{US,t}\left(h_{t-1}^{US}\right) + \alpha^2{}_{US,t}(\epsilon_{US,t-1}^2) + \beta^2{}_{BRICS,t}\left(h_{t-1}^{BRICS}\right) + \alpha^2{}_{BRICS,t}(\epsilon_{BRICS,t-1}^2) \quad (4)$$

The GARCH (1, 1) framework which models the conditional variance (h_t^{BRICS} and h_t^{US}) of the returns of the BRICS and the US stock market in equation (3) and (4) respectively is primarily a function of a constant, lag of conditional variances of the BRICS stock market and the US stock market, and the lag of the squared residuals of the respective markets. $C^2{}_{BRICS}$ and $C^2{}_{US}$ represents the constant term. The terms of the equation, $h^{BRICS}{}_{t-1}$ and $h^{US}{}_{t-1}$ refers to the lag of the conditional variances at time t-1 of the BRICS and the US stock market respectively. The term captures the impact of lagged conditional volatilities, i.e., the BRICS and the US stock market volatility spillovers. The term $\varepsilon^2{}_{BRICS,t-1}$ and $\varepsilon^2{}_{US,t-1}$ refers to the cross-value of error terms which represents the return innovations of the BRICS and the US market at time t-1 respectively. The volatility transmission across the two stock markets over time is governed through the cross-value of error terms and the lag of the squared residuals captures the direct impact of shock transmissions between the stock markets (Lin et al., 2014). The lags of the conditional variances indicate long-run persistence of past volatilities (GARCH effects) and the lag of the squared residuals indicates the short-run persistence (ARCH effects) of past shocks. The size of α and β coefficients used in the equations determines the short run dynamics of the underlying stock market return volatility. The coefficient α measures the extent to which current volatility shocks feed through into next period's volatility and the β coefficient depict volatility persistence. The α coefficient implies the size of reaction and the large value of α indicates strong volatility

reactions to market movements and large β means a long time is required for volatility shocks to fade away (Syriopoulos et al., 2015). Moreover, the equation 3 and 4 helps us to estimate the transmission of volatility and shocks from one stock market to another stock market return indices across the sample time period.

Furthermore, equation 5 helps us to estimate conditional covariance of the returns in the US and BRICS stock market return indices as below:

$$h_t^{BRICS,US} = \rho_t \sqrt{h_t^{BRICS}} \sqrt{h_t^{US}} \qquad (5)$$

In equation 5, P_t is the conditional constant correlation (CCC) between the BRICS and the US stock market return at time t. The equation 5 models the conditional covariance between returns of the BRICS and the US stock market which can handle a bigger set of variables than the more fully parameterized models. Nevertheless, the constancy assumption of CCC can be viewed as restrictive as correlation coefficient is likely to vary over time. The stock market indices tend to change according to changes in economic situations, investor's expectations and market conditions (Syriopoulos et al., 2015). I have used the VAR-GARCH model in my paper that allows modeling the dynamic conditional correlations. However, it is also considered to have some empirical and theoretical limitations (McAleer, Hoti & Chan, 2009; Arouri et al., 2012).

In general, normality conditions are often rejected for financial series and the QMLE technique is robust to any departure from such normality conditions (Ling & McAleer, 2003). Therefore, I have applied the QMLE technique to capture the non-normality associated with stock prices and obtain the estimates of the parameters of VAR-GARCH model for the return data.

5. EMPIRICAL RESULTS

This section of my thesis includes findings of the study and presents empirical analysis for the results of the empirical methodology used to investigate the volatility spillover and transmission between stock market of the US and the BRICS. The section presents result for data sample of full period and three different sub-periods that includes analysis of the global financial crisis 2007-09 as the crisis period.

5.1. Estimation results and discussion

The estimation results of VAR (1)-GARCH (1, 1) framework as the econometric model to examine the volatility spillover between the US and the BRICS market are presented from table 10 to table 14. The estimates of the mean conditional equation specified by equation (1) and conditional variance of the stock market returns specified by equation (3) and (4) for respective stock market of the BRICS nations and the US are reported in the result tables for full sample period and three sub-periods.

Table 10 presents the result of the VAR (1)-GARCH (1, 1) model for stock market of Brazil. The result of mean equation shows that current return of Brazilian stock market is not affected by its own past return with exception after the crisis (0.1501). The US stock market is significantly affected by its own lagged returns for all sample period with exception during the crisis period (0.0460). The lagged returns of Brazil does not have any impact on current stock return of the US with exception of having have negative and significant impact on the US market before (-0.1491) and after the crisis (-0.2364). The result of the US market shows that it has positive impact on the Brazilian stock market during the pre-crisis period (0.0361) and after the crisis (0.0446) only. The result of the mean equation suggest that past return of the Brazilian stock market cannot be used to predict the current returns, whereas the case is different for the US. However, the scenario for both markets during the crisis period is different and result shows that current stock market is not affected by past returns and one market lagged-returns does not affect each other during the crisis.

Table 10.Estimation result of VAR (1)-GARCH (1, 1) model for Brazil.

Period	Full Period		Pre-Crisis		Crisis		Post-Crisis	
Independent Variable	Brazil	US	Brazil	US	Brazil	US	Brazil	US
Mean Equation								
r^{B}_{t-1}	-0.0384	-0.0324	-0.0317	-0.1491	-0.1748	0.2793	0.1501	-0.2364
	(0.33)	(0.71)	(0.39)	(0.01)[a]	(0.24)	(0.26)	(0.01)[a]	(0.03)[b]
r^{US}_{t-1}	-0.0078	-0.1152	0.0361	-0.2485	-0.0725	0.0460	0.0446	-0.1513
	(0.64)	(0.00)[a]	(0.07)[c]	(0.00)[a]	(0.20)	(0.71)	(0.00)[a]	(0.00)[a]
Variance Equation								
$\varepsilon^{2}_{B,t-1}$	0.0495	0.4934	-0.0522	1.1762	0.1109	0.3105	0.0855	0.3926
	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.06)[c]	(0.02)[b]	(0.00)[a]	(0.00)[a]
$\varepsilon^{2}_{US,t-1}$	0.0111	0.1454	0.0023	0.2075	-0.0385	0.4605	-0.0097	0.2108
	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]
h^{B}_{t-1}	0.9396	-0.6904	-0.4592	2.8296	0.8526	-0.8759	0.8840	-0.7449
	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]
h^{US}_{t-1}	-0.0121	0.7981	-0.0953	1.0335	0.0786	0.1870	0.0361	0.4931
	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.05)[c]	(0.20)	(0.00)[a]	(0.00)[a]

Notes: The table reports the findings of VAR (1)-GARCH (1, 1) model for stock market of Brazil and the US for full data sample period (January 2000 to December 2016), and three sub periods as pre-crisis period (January 2000 to June 2007), the crisis period (July 2007 to June 2009) and the post crisis period (July 2009 to December 2016). The result contains result for mean conditional equation specified by equation (1), and conditional variance of the stock market returns specified by equation (3) and (4). r^{B}_{t-1} and r^{US}_{t-1} refers to the return of the Brazilian stock market and the US stock market at time t-1 respectively. h^{B}_{t-1} and h^{US}_{t-1} captures the conditional variances of the Brazilian stock market and the US stock market at time t-1 respectively. $\varepsilon^{2}_{B,t-1}$ and $\varepsilon^{2}_{US,t-1}$ refers to the cross-value of error terms which measures the return innovations (shock) of the Brazil and the US market at time t-1 respectively. a, b and c indicates statistical significance at 1%, 5% and 10% levels respectively. The values in parentheses denote p values.

The result of variance equation shows coefficients for the ARCH terms and the GARCH terms. The ARCH terms ($\varepsilon^{2}_{B,t-1}$ & $\varepsilon^{2}_{US,t-1}$) captures the impact of past shocks on current conditional volatility. Similarly, the GARCH terms (h^{B}_{t-1} & h^{US}_{t-1}) measure the impact of past volatility on current volatility. If the coefficients of ARCH terms are relatively small in size, conditional volatility does not change very rapidly. Whereas, the large magnitude of GARCH-term estimates indicates gradual fluctuations of conditional volatility over time (Arouri, Lahiani & Nguyen, 2011). When we look at the effect of past shocks, the result indicates that the US stock market have significant effects on volatility of the Brazilian markets for all periods. It means that the conditional volatility of the Brazilian stock market is affected by innovations (shocks) in the US market as indicated by the estimated coefficient of $\varepsilon^{2}_{US,t-1}$ at 1% significance level. The result suggests that shocks or any sorts of news originating from the US market will affect the stock

market of Brazil and increase its current volatility. The case is similar for the US stock market as shown by $\varepsilon^2_{B,t-1}$ which suggest that current volatility of the US stock market is affected by past shocks of the Brazilian stock market. Furthermore, the result shows the significant impact on current volatility of the Brazilian stock market from past volatility of the US. The situation is similar for stock market of the US as shown by coefficients of h^B_{t-1} which are significant at 1% level for all periods. The past volatility of the US stock market is transmitted to the Brazilian stock market as suggested by significant GARCH term (h^{US}_{t-1}) which is significant at 1% significance level for all period, except during the crisis period at 10% level (0.0786). Moreover, the result suggests that both markets are hugely influenced by their own-lagged past shocks as well as own past volatility. The result of VAR (1)-GARCH (1, 1) model used for stock market of the Brazil is similar with the findings of Arouri, Lahiani & Nguyen (2015) who has employed the same methodology for the period of 1993-2012 to study Latin American equity markets.

The estimation results of the VAR (1)-GARCH (1, 1) model for the stock market of Russia is presented in table 11. The result of mean equation shows that Russia does not play any significant role in the stock market of the US. The result is similar in case of the US market also. The result suggests that current stock returns of Russia are not affected by its own past returns. However, during the crisis, the result is different from the above mentioned cases, and suggest that for both markets past own lagged-returns can be used to predict the own current returns. Similarly, the past returns of Russian market help to predict the current returns of the US, and the lagged returns of the US market also have significant effects on the current market of Russia. The finding indicates short-term predictability in each market. Moreover, after the crisis period, the result is totally different than the crisis period. The result shows that both markets do not have any relation with each other. The result also shows that current stock returns of the US stock market is significantly affected by its own past returns with exception (-0.0729) to after crisis period. The estimates of the variance equation shows that the current volatility of the Russian stock market is not affected by any past shocks form the US market as indicated by the estimated coefficient of $\varepsilon^2_{US,t-1}$ at 1% significance level, except during the crisis period. Similarly, the GARCH term h^{US}_{t-1} shows that there is not any significant impact on current volatility of the Russian stock market from past volatility of the US, except during the crisis period. This result suggests that the stock market of Russia behaves independently during the

normal period and impact is seen only in turmoil period. Moreover, the result shows that both market are significantly influenced by their own lagged shocks and own past volatility, except for Russia (0.0555, after crisis) and US (0. 0353, before crisis). During the crisis period, we can find the evidence that past volatility and shocks from the US are transmitted to Russian market and the market was affected significantly. The result for crisis period supports the findings of previous study by Dooley & Hutchison (2009), which states that Russia was most affected compared to China during the financial turmoil period and the Lehman Brothers Bankruptcy news and associated announcements was the main event which significantly affected most of the emerging markets. The findings for the post-crisis period supports the result of Mensi, et al. (2016) which did not find spillovers in the Russian stock market and indicates a sign of isolation (decoupling) between these two markets after the crisis.

Table 11. Estimation results for Russian stock market.

Period	Full Period		Pre-Crisis		Crisis		Post-Crisis	
Independent Variable	Russia	US	Russia	US	Russia	US	Russia	US
Mean Equation								
r^{R}_{t-1}	-0.0330	0.0439	0.0064	0.1956	-0.2663	0.4264	-0.0670	0.0212
	(0.32)	(0.47)	(0.90)	(0.07)[c]	(0.00)[a]	(0.00)[a]	(0.30)	(0.83)
r^{US}_{t-1}	-0.0079	-0.0856	-0.0044	-0.0959	-0.0654	-0.1271	0.0012	-0.0729
	(0.58)	(0.01)[a]	(0.81)	(0.05)[c]	(0.00)[a]	(0.00)[a]	(0.97)	(0.22)
Variance Equation								
$\varepsilon^2_{R,t-1}$	0.1022	0.2889	0.0768	0.0446	0.2140	0.4620	0.0555	0.3526
	(0.00)[a]	(0.00)[a]	(0.05)[c]	(0.57)	(0.00)[a]	(0.00)[a]	(0.15)	(0.00)[a]
$\varepsilon^2_{US,t-1}$	-0.0003	0.1722	-0.0048	0.0353	-0.0322	0.5648	-0.0021	0.1587
	(0.95)	(0.00)[a]	(0.11)	(0.12)	(0.00)[a]	(0.00)[a]	(0.82)	(0.00)[a]
h^{R}_{t-1}	0.8771	-0.3428	0.8625	0.0256	0.4069	-0.0891	0.9444	-0.8080
	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.84)	(0.00)[a]	(0.37)	(0.00)[a]	(0.04)[b]
h^{US}_{t-1}	0.0046	0.7601	0.0127	0.9447	0.0436	0.0798	0.0369	0.6016
	(0.48)	(0.00)[a]	(0.10)	(0.00)[a]	(0.00)[a]	(0.03)[b]	(0.53)	(0.00)[a]

Notes: The table reports the findings of VAR (1)-GARCH (1, 1) model for stock market of Russia and the US for full data sample period (January 2000 to December 2016), and three sub periods as pre-crisis period (January 2000 to June 2007), the crisis period (July 2007 to June 2009) and the post crisis period (July 2009 to December 2016). The result contains result for mean conditional equation specified by equation (1) and conditional variance of the stock market returns specified by equation (3) and (4). r^{R}_{t-1} and r^{US}_{t-1} refers to the return of the Russian stock market and the US stock market at time t-1 respectively. h^{R}_{t-1} and h^{US}_{t-1} captures the conditional variances of the Russian stock market and the US stock market at time t-1 respectively. $\varepsilon^2_{R,t-1}$ and $\varepsilon^2_{US,t-1}$ refers to the cross-value of error terms which measures the return innovations (shock) of the Russia and the US market at time t-1 respectively. a, b and c indicates statistical significance at 1%, 5% and 10% levels respectively. The values in parentheses denote p values.

Table 12 provides results from VAR (1)-GARCH (1, 1) model for the Indian stock market and the US which includes details about returns of respective market, volatilities and spillover effects. The result of mean equation shows that past returns of Indian stock market significantly affect the current returns of the US stock market, while the case for the US stock market is different. The result suggest that current values of the Indian stock market is not affected by own lagged-returns, whereas it is not similar for the US stock market (except -0.0779 post-crisis period). However, during the crisis, the result is different, and we can witness that past returns can be used to predict the current returns for both markets. The result shows that the US stock market does have negative impact (-0.0588) at 10% significance level on Indian stock market during the crisis.

The result of VAR and GARCH estimates appears to be highly significant for all sample periods with few exceptions. The coefficients of ARCH term $\varepsilon^2_{US,t-1}$ suggests that the stock market of India is significantly affected by the shocks transmitted from the US market, with exception after the crisis (0.0057). A shock originating from the US market seems to be transmitted to the Indian market as indicated by 10% level of coefficient on $\varepsilon^2_{US,t-1}$ (0.0191) for the full period, and at 1% level on pre-crisis and crisis period. However, the past volatility in the US stock market does not influence the current volatility of the Indian market for full period (-0.0072). But the situation is different for rest of the sample periods. The result shows evidence of volatility spillover in Indian market from the US stock market and supports the previous findings on study of BRIC equity markets. Bhar & Nikolova (2009) study on BRIC equity markets for period of 1995 to 2006 by using weekly closing equity market price indices, finds the evidence of volatility spillover in Indian Market from the world market. Abbas et al. (2013) study on Asian stock market finds that the volatility coefficient of the US for the Indian market is significant at 1% significance level and highlights the reason of the significant value as the increasing role of the US in Indian affairs during the sample period (1997 to 2009). However, after the 2007-09 crisis, the situation is slightly different as my result shows that shocks from the US are not transmitted, rather affected by own-lagged news and own past volatility. The impact of US stock market´s past volatility on the Indian market is negatively significant (-0.1366) at 10 % level after the crisis. The result shows that both stock market are significantly influenced by their own lagged shocks and own

past volatility rather than cross-market impact as indicated by the 1% significance level for coefficients of the ARCH and GARCH terms for all sample periods.

Table 12. Estimation results for India and the US stock market.

Period	Full Period		Pre-Crisis		Crisis		Post-Crisis	
Independent Variable	India	US	India	US	India	US	India	US
Mean Equation								
r^{I}_{t-1}	0.0310 (0.41)	0.1501 (0.00)[a]	0.0816 (0.15)	0.1970 (0.02)[b]	-0.1770 (0.00)[a]	0.2976 (0.00)[a]	-0.0491 (0.40)	0.1569 (0.01)[a]
r^{US}_{t-1}	0.0018 (0.94)	-0.0831 (0.03)[b]	-0.0120 (0.69)	-0.0757 (0.09)[c]	-0.0588 (0.05)[c]	-0.1511 (0.00)[a]	-0.0182 (0.66)	-0.0779 (0.16)
Variance Equation								
$\varepsilon^2_{I,t-1}$	0.1106 (0.00)[a]	0.1691 (0.00)[a]	0.1570 (0.00)[a]	0.2532 (0.00)[a]	0.1069 (0.00)[a]	-0.0874 (0.00)[a]	0.1437 (0.02)[b]	0.0380 (0.56)
$\varepsilon^2_{US,t-1}$	0.0191 (0.08)[c]	0.2029 (0.00)[a]	0.0353 (0.00)[a]	0.0394 (0.00)[a]	0.1829 (0.00)[a]	0.2431 (0.00)[a]	0.0057 (0.77)	0.1984 (0.00)[a]
h^{I}_{t-1}	0.8545 (0.00)[a]	-0.1808 (0.00)[a]	0.6624 (0.00)[a]	0.0882 (0.00)[a]	-0.7139 (0.00)[a]	0.9953 (0.00)[a]	0.6177 (0.00)[a]	0.0414 (0.72)
h^{US}_{t-1}	-0.0072 (0.68)	0.7190 (0.00)[a]	-0.0662 (0.00)[a]	1.0224 (0.00)[a]	-1.1196 (0.00)[a]	0.9607 (0.00)[a]	-0.1366 (0.07)[c]	0.6990 (0.00)[a]

Notes: The table reports the findings of VAR (1)-GARCH (1, 1) model for stock market of India and the US for full data sample period (January 2000 to December 2016), and three sub periods as pre-crisis period (January 2000 to June 2007), the crisis period (July 2007 to June 2009) and the post crisis period (July 2009 to December 2016). The result contains result for mean conditional equation specified by equation (1) and conditional variance of the stock market returns specified by equation (3) and (4). r^{I}_{t-1} and r^{US}_{t-1} refers to the return of the Indian stock market and the US stock market at time t-1 respectively. h^{I}_{t-1} and h^{US}_{t-1} captures the conditional variances of the Indian stock market and the US stock market at time t-1 respectively. $\varepsilon^2_{I,t-1}$ and $\varepsilon^2_{US,t-1}$ refers to the cross-value of error terms which measures the return innovations (shock) of the India and the US market at time t-1 respectively. a, b and c indicates statistical significance at 1%, 5% and 10% levels respectively. The values in parentheses denote p values.

The estimates of the VAR (1)-GARCH (1, 1) model for the Chinese stock market are reported in table 13. The result for the stock market of China and the US mean equation shows that past return of Chinese markets can be used to predict the current returns of own market and the US market for all sample period, with exception after the crisis period. Similarly, the lagged return of the US market shows that coefficients for current returns of the US stock market are negative and significantly affected by its own past returns for all sample periods. However, the result suggests that the past returns of the US stock market do not helps to predict the current returns of China. However, the situation is different during the crisis. The result for crisis period suggests

that in both markets, current returns can be predicted by past returns. The result indicates that both markets can be predicted in short-term.

Table 13. Estimation result of VAR (1)-GARCH (1, 1) model for China.

Period	Full Period		Pre-Crisis		Crisis		Post-Crisis	
Independent Variable	China	US	China	US	China	US	China	US
Mean Equation								
r^{C}_{t-1}	-0.1155 (0.00)[a]	0.2305 (0.00)[a]	-0.1351 (0.02)[b]	0.3414 (0.00)[a]	-0.0704 (0.00)[a]	0.3225 (0.00)[a]	-0.0503 (0.39)	0.1329 (0.11)
r^{US}_{t-1}	-0.0211 (0.32)	-0.0852 (0.02)[b]	-0.0133 (0.67)	-0.1089 (0.05)[c]	-0.0060 (0.00)[a]	0.0290 (0.00)[a]	0.0051 (0.89)	-0.0952 (0.08)[c]
Variance Equation								
$\varepsilon^2_{C,t-1}$	0.0755 (0.00)[a]	0.1072 (0.01)[a]	0.0774 (0.01)[b]	0.0012 (0.97)	0.0967 (0.00)[a]	0.0448 (0.42)	-0.0022 (0.92)	0.1148 (0.11)
$\varepsilon^2_{US,t-1}$	0.0012 (0.87)	0.1654 (0.00)[a]	0.0034 (0.60)	0.0396 (0.08)[c]	-0.0305 (0.00)[a]	0.3220 (0.00)[a]	-0.0057 (0.70)	0.0968 (0.02)[b]
h^{C}_{t-1}	0.9190 (0.00)[a]	-0.1692 (0.01)[a]	0.8959 (0.00)[a]	0.0223 (0.71)	0.4463 (0.00)[a]	0.0425 (0.24)	0.1811 (0.84)	0.9765 (0.42)
h^{US}_{t-1}	0.0313 (0.03)[b]	0.7201 (0.00)[a]	0.0032 (0.73)	0.9395 (0.00)[a]	-0.0117 (0.00)[a]	0.3515 (0.00)[a]	-0.5132 (0.41)	1.5613 (0.07)[c]

Notes: The table reports the findings of VAR (1)-GARCH (1, 1) model for stock market of China and the US for full data sample period (January 2000 to December 2016), and three sub periods as pre-crisis period (January 2000 to June 2007), the crisis period (July 2007 to June 2009) and the post crisis period (July 2009 to December 2016). The result contains result for mean conditional equation specified by equation (1) and conditional variance of the stock market returns specified by equation (3) and (4). r^{C}_{t-1} and r^{US}_{t-1} refers to the return of the Chinese stock market and the US stock market at time t-1 respectively. h^{C}_{t-1} and h^{US}_{t-1} captures the conditional variances of the Chinese stock market and the US stock market at time t-1 respectively. $\varepsilon^2_{C,t-1}$ and $\varepsilon^2_{US,t-1}$ refers to the cross-value of error terms which measures the return innovations (shock) of the China and the US market at time t-1 respectively. a, b and c indicates statistical significance at 1%, 5% and 10% levels respectively. The values in parentheses denote p values.

The coefficients of ARCH term $\varepsilon^2_{US,t-1}$ suggests that there is not any transmission of shock to China from the US market, with exception to the crisis period. The findings support the idea of previous works which states that in general, stock markets in both China and India are less dependent on the US shocks (Aloui, et al., 2011). The result shows interesting findings that the ARCH term which captures the impact of the market's own lagged standardized innovations on the conditional volatility and the GARCH term which captures the impact of past volatility for the US stock market is significantly influenced by its own-lagged shocks and own past volatility for all sample periods. However, the impact of $\varepsilon^2_{US,t-1}$ term is smaller compared to own volatility.

The US market seems to be more volatile the after the crisis (1.5613) as compared to rest of the sample period followed by pre-crisis period (0.9395). The case for China is also similar with exception to the post-crisis period (-0.0022 & 0.1811) and the Chinese market is more volatile for full period (0.9190) followed by before the crisis period (0.8959) and the crisis period. In addition, the coefficients of GARCH term (h^{US}_{t-1}) is significant and suggest that past volatility of the US stock market is transmitted to stock market of China for full period and during the crisis only. Similarly, the result of volatility coefficient for the US from stock market of China is insignificant for all periods as indicated by h^{C}_{t-1} with exception to full period (-0.1692). During the crisis period, the volatility spillover effect of the US market is negatively significant on volatility of the Chinese market (-0.0305) and past volatility of the US market affects the current volatility of the Chinese market (-0.0117). The non-existence of impact from Chinese stock market on the US supports the findings of Bekiros (2014) which suggest that China has relatively less influence on stock price movements in the US and plays a passive role in information transmission to other stock market.

The estimates of the VAR (1)-GARCH (1, 1) model for the stock market of South Africa is presented in table 14. The finding of mean equation suggest that past stock return of South Africa has influence on its current return and interestingly affects the current return of the US, with exception before the crisis period. During the pre-crisis period, there is not any evidence of impact on current returns for both markets from own lagged-returns as well as from other market's past returns. The current return of the US stock market is not affected by its own past return (has impact only for full period at 5% significance level) and does not have any impact on current return of stock market of South Africa for all sample periods. The insignificant coefficients of the mean equation for South Africa supports the findings of Dimitriou et al. (2013) which provides evidence of insulated (decoupled) stock market of South Africa from the US and the global financial crisis. The coefficients of ARCH term $\varepsilon^{2}_{US,t-1}$ suggests that there is transmission of shock from the US market to stock market of South Africa (-0.1192) only during the crisis. The result shows that the US stock market is significantly influenced by its own-lagged shocks as well as own past volatility for all sample periods, with exception to pre-crisis period (0.0254 & 0.6082). The stock market of South Africa also has similar case of impact from its own-lagged shocks with exception to pre-crisis period (-0.0353) and significantly affected by

its own past volatility for all periods. The coefficients of GARCH term (h^{US}_{t-1}) suggest that past volatility of the US stock market does not have any impact on stock market of South Africa. The findings suggest that the stock market of South Africa performs independently and even though shock is transferred during the crisis, volatility of the US market does not affect the stock market of South Africa in the crisis period also. The findings indicates that both markets are predicted and affected more by their own past lags, shocks and volatility and there is minimal cross-market effect between each other.

Table 14. Estimation result for stock market of South Africa.

Period	Full Period		Pre-Crisis		Crisis		Post-Crisis	
Independent Variable	South Africa	US	South Africa	US	South Africa	US	South Africa	US
Mean Equation								
r^{S}_{t-1}	-0.1318 (0.00)[a]	0.0986 (0.02)[b]	-0.0798 (0.15)	0.0987 (0.19)	-0.2029 (0.00)[a]	0.1672 (0.00)[a]	-0.1617 (0.01)[a]	0.1080 (0.07)[c]
r^{US}_{t-1}	-0.0347 (0.23)	-0.0820 (0.03)[b]	-0.0588 (0.17)	-0.0925 (0.11)	0.0763 (0.31)	-0.1246 (0.15)	-0.0008 (0.99)	-0.0894 (0.12)
Variance Equation								
$\varepsilon^2_{S,t-1}$	0.0501 (0.01)[a]	0.0974 (0.00)[a]	-0.0353 (0.18)	0.1027 (0.07)[c]	-0.2288 (0.00)[a]	0.2368 (0.00)[a]	0.0781 (0.01)[a]	0.0629 (0.03)[b]
$\varepsilon^2_{US,t-1}$	0.0246 (0.15)	0.1851 (0.00)[a]	0.0272 (0.48)	0.0254 (0.48)	-0.1192 (0.00)[a]	0.4004 (0.00)[a]	0.0359 (0.15)	0.1187 (0.02)[b]
h^{S}_{t-1}	0.9518 (0.00)[a]	-0.1446 (0.00)[a]	0.4820 (0.06)[c]	0.3224 (0.10)	0.5057 (0.00)[a]	0.1860 (0.00)[a]	0.8770 (0.00)[a]	-0.1494 (0.01)[b]
h^{US}_{t-1}	-0.0067 (0.78)	0.7439 (0.00)[a]	0.4344 (0.37)	0.6082 (0.13)	-0.0368 (0.44)	0.4846 (0.00)[a]	-0.0613 (0.13)	0.7688 (0.00)[a]

Notes: The table reports the findings of VAR (1)-GARCH (1, 1) model for stock market of South Africa and the US for full data sample period (January 2000 to December 2016), and three sub periods as pre-crisis period (January 2000 to June 2007), the crisis period (July 2007 to June 2009) and the post crisis period (July 2009 to December 2016). The result contains result for mean conditional equation specified by equation (1) and conditional variance of the stock market returns specified by equation (3) and (4). r^{S}_{t-1} and r^{US}_{t-1} refers to the stock market's return of South Africa and the US at time t-1 respectively. h^{S}_{t-1} and h^{US}_{t-1} captures the conditional variances of the South African stock market and the US stock market at time t-1 respectively. $\varepsilon^2_{S,t-1}$ and $\varepsilon^2_{US,t-1}$ refers to the cross-value of error terms which measures the return innovations (shock) of the South Africa and the US market at time t-1 respectively.a, b and c indicates statistical significance at 1%, 5% and 10% levels respectively. The values in parentheses denote p values.

In summary, the result of mean equations shows that returns of Russia, India and China have cross-market effect with the US during the crisis period with exception to Brazil and South

Africa. This suggest that in terms of information transformation, past returns of the US affect current returns of Russia, India and China during the crisis period with exception to Brazil and South Africa. On the other hand, stock market of BRICS nations also has an impact on the US with exception to the stock market of Brazil during the crisis period. It means that past returns of both markets can be incorporated to short-term return predictions during the global financial crisis period. However, when I see the estimated result for return of each BRICS market, the result indicates that one-period lagged return values of the respective market has very minimal role and market of Brazil, Russia and India even does not have any impact to determine their own current values. During the crisis period, the case is different and there is evidence of impact. However, Brazil is exception even in the crisis and China is the one mostly affected by its own one-period lagged returns. Similarly, when we see the VAR-GARCH equations for both stock returns series, the coefficients of the GARCH term are relatively larger than the coefficients of the ARCH term for most of the sample periods with some exception during the crisis and the sums of the GARCH and ARCH coefficients are even close to one. This reflects somehow consistent result with the findings of Zhang, at al. (2013) study on BRICS which indicates the persistent influence of shocks on return volatilities. The findings of my empirical analysis for stock market of the five BRICS nations with relation to the US shows that most of the BRICS nations are affected during the global financial crisis period rather than the normal period. This implies that stock market disturbances from the US are transmitted to these nations which might have adverse consequences for stability of the financial system (Lahrech & Sylwester, 2011). The result shows only Brazil has volatility spillover effect from the US in normal period also. Russia is the one which is not affected during the normal period followed by South Africa and China and India. This shows that most of the BRICS stock market behaves independently during the normal period. India and China do have some impact from volatilities of the US stock market in normal period also. Despite of having an impact on current volatilities before the crisis (India) and crisis period (India and China), the past return shocks and past conditional volatilities of the US does not have any impact on India (has minimum effect only from past volatilities) and China after the crisis period. The findings reveal that all BRICS market have significant effects of own-lagged past return innovations (shocks) and past conditional volatilities on their current volatilities.

6. CONCLUSION

We can find numerous research papers and study on transmission of volatility and spillover effect between the US and BRICS stock markets. My study on stock market volatility and spillover effect highlights the context of financial turmoil and normal period during year 2000 to 2016. I employed multivariate GARCH framework on weekly MSCI return indices of respective stock market of the BRICS nations to investigate both the mean return and volatility spillover effect from stock market of the US to the BRICS. My study contributes to the literature on stock market return and volatility spillover effects between BRICS (Brazil, Russia, India, China and South Africa) as the emerging markets and the US as developed market in the world economy. The study period is divided into full period and three sub-periods which include normal period as well as the global financial crisis 2007-09 as the crisis period. The global financial crisis period of 2007-09 represents the financial stress period for stock market of the BRICS nation. The problem in the US housing market is considered as the primary reason for the crisis in the US followed by subsequent global financial crisis of 2007-09. The findings of my study confirm the presence of spillover effects between the BRICS nations and the US during the crisis period and support the second hypothesis of my study. The evidence can also be confirmed by recent literature on stock market volatility spillover between emerging markets and the developed markets in context of various financial crisis periods. The study by Rejeb & Arfaoui (2016) on stock market interdependence in terms of volatility transmission confirms the presence of transmission of return shocks during the crisis period between emerging markets and developed markets. The result of my study shows similar result on information transmission from mean equation and volatility spillover effects from past shocks and volatility between the US and BRICS stock markets with exception to Brazil during the crisis period. The stock market of Brazil shows that there is not any impact on information transmission from the US even in the crisis period as indicated by coefficients of the mean equation. However, the volatility transmission model has captured the effect of volatility spillover effects between the US and Brazil during the crisis as well as normal period.

Furthermore, market of Russia, South Africa and China are the least affected by volatility of the US market in the normal period followed by some impact on India. The past return innovations

and past volatility of the US market has significant effects on the conditional volatility of Brazilian stock market. This provides the evidence of volatility spillover between the US and Brazil is high as compared to rest of the BRICS nations. It indicates relatively high level of trade openness between these two markets and suggests that tight economic linkages between countries make a particular country more sensitive and vulnerable to shocks occurred in the other countries (see Arouri, et al., 2015). The presence of volatility transmission in Brazilian stock market supports the first hypothesis of my thesis. However, the situation of Russia, South Africa and China is totally different than the market of Brazil and rejects the first hypothesis in most of the cases. The findings for Russia confirm earlier evidence of not having any spillover from the US during the normal period and behaving independently after the crisis period (Mensi, et al, 2016). The situation is almost similar for South Africa, China and India. Although the market of China and India are not affected as much as Brazil, both markets are affected at some level by past return shocks and volatilities from the US stock market. The presence of very minimal co-movements between the Chinese and the US stock market implies that China has controlled economy with huge amount of foreign reserves which can protect their market and behave independently (Mensi et al, 2014). Despite having the evidence of volatility spillovers from Brazil to the US, the result shows very minimal impact from BRICS countries to the US market. The result interestingly shows short term influence of South Africa on the US. The findings can be used for further analysis on volatility spillover between stock market of South Africa and the US. Despite having some negative impact on China during the crisis, the stock market of US is not affected by return shocks and past volatilities from the China, with minimal impact for full sample period. Although my study contributes on existence literature of stock market of the BRICS nations, the increasing influence in the international stock market and significant role played by such emerging nations in the global economy suggest that we need to do more research and study the behavior of these markets during the normal period as well as financial turmoil periods. The economic performance of such nations will play important role to recover from such financial crisis in the future. The study on volatility and shock transmission between stock markets also has some practical implications for international investors as well as market participants (Noor & Dutta, 2017) and the findings of my study might assist policy makers as well as investor to formulate market regulations and investment strategies.

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APPENDIX

[1]According to Bekaert, Ehrmann, Fratzscher & Mehl (2014), the starting point of the crisis is August 2007 when equity market of the US started to fell and financial market started to have the problem of liquidity. The equity market declined about 50% during about 18 months of the crisis period (mid 2007 to early 2009). The collapse of Lehman Brothers on September 2008 is considered as peak and alternative starting point of the crisis. We can find various papers that have followed similar approach to divide the sample period has on the basis of financial crisis 2007-09 (like Turtle and Wang, 2016, has used data from 2007 to 2013 and divided the sample data as pre-crisis, crisis and post-crisis period).

[2]On June 2007, some of the big financial institutions of the USA (like JP Morgan Chase, Merrill Lynch, Citigroup and Goldman Sachs) became aware about the problem in subprime mortgages; period around the end of July 2007 to first week of August 2007, considered as the sub-prime crisis period where the global stock markets were affected significantly and Dow Jones Index and shares plunged heavily with a fears of sub-primes losses and global credit crunch (BBC News, 2008).