LINKAGE DYNAMICS

BETWEEN FINANCIAL MARKETS IN INDIA:

AN EMPIRICAL STUDY

A thesis submitted to Goa University for the Award of the Degree of

DOCTOR OF PHILOSOPHY

IN

COMMERCE

BY

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UNDER THE GUIDANCE

OF

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Dedicated to my son,

Daksh

my parents,

Smt. Sheela Ingalhalli and Shri. B.S. Ingalhalli

&

my grandparents,

Smt. Shanta Maragal and Shri. V.M. Maragal

DECLARATION

*I, Ms. Varsha B. Ingalhalli, hereby declare that the thesis titled, "**Linkage Dynamics between Financial Markets in India: An Empirical Study**", submitted to Goa University, Goa, for the award of the degree of Doctor of Philosophy, is the outcome of original and independent research work undertaken by me during the period 2012-2018. The study is carried out under the supervision and guidance of Prof. Y. V. Reddy, Professor, Department of Commerce, Goa University, Goa.*

It has not been previously formed the basis for the award of any degree, diploma or certificate of this or any other universities. I have duly acknowledged all the sources used by me in the preparation of thesis.

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CERTIFICATE

*Certified that the work incorporated in the thesis, "**Linkage Dynamics between Financial Markets in India: An Empirical Study**", submitted by Ms. Varsha B. Ingalhalli was carried out under my guidance. The result of research presented in the thesis has not previously formed the basis for the award of any degree, diploma or certificate of this or any other university.*

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 INTRODUCTION

Liberalization, Globalization and technological advancements have made the financial markets in India more integrated domestically and internationally over a period of time. Due to this increased integration, events affecting one market invariably have an impact on the inter-linked markets, thereby influencing the returns on investments of investors diversifying their portfolio internationally (Morales, L., 2009). Also, at the time of occurrence of any event/ shock/announcement in the financial markets, investors use asset allocation strategy to shift their investments among the markets (stock, commodity, foreign exchange and/or money markets etc.) so as to reduce risk and increase returns. The interlinked and symbiotic market dynamics, hence, necessitate a study of linkage dynamics among important asset classes and analysing their co-movements. This co-movement analysis of financial markets will help institutional and individual investors in better managing their portfolios.

Increased cross-border trade in goods and services and cross-border investment for portfolio diversification to reduce portfolio risk has led to greater integration among financial markets across the world. This cross-border trading has increased substantially in past years since liberalization and globalization; this is on account of high competition within the economy and increase in the customer base due to the opportunities arising in other economies. The liberalization process has allowed domestic companies to source their capital requirement from all around the world. All this has led to an increased correlation among the financial markets of economics across the world. Thus, providing investors with an opportunity to diversify investment portfolios with an expectation to reduce risk and increase the returns on investments based on the correlation among the

financial markets. And, this has resulted in an increased flow of funds into and out of the economy.

With economic globalization has come an increasing interdependence of world economies on account of rising cross-border transactions in relation to commodities and services, international capital flows and rapid spread of technologies. International Finance first came into being to cater to the needs of international trade and investment activities, with the development of economic globalization; today, it has become an independent sector. While Multinational Corporations (MNCs) are the key players of this globalized economy, financial globalization is its most developing and influential element.

Thus, the study aims at broadly understanding the dynamic linkages among the financial markets in India by examining volatility linkages among them. Stock market investments being an integral component of the financial planning process, are affected by various factors such as fluctuations in exchange rate, announcement of macro-economic variables, and political volatility amongst others. Globalization and liberalization of capital flows have led to huge foreign investments in Indian equity market thereby making the two markets highly interdependent (Palakkod, S., 2012). Interactions between the stock market and foreign exchange market have been a subject of interest and debate for not only investors, but also for academicians and researchers. This can be understood by studying the crucial role the two markets play in facilitating and enhancing the economic activities within and across the countries. The two main classic theories explaining the interactions among the markets are, "Goods Market Approach" and "Portfolio Balanced Approach". The former, first brought out by Dornbusch and Fisher (1980), postulates that stock price movements are affected by

movements in the foreign exchange market. Stock market prices reflect a firm's cash flow if the market is an efficient market as suggested by Fama (1965) through his Efficient Market Hypothesis, and this is an underlying macroeconomic view for developing the theory, wherein foreign exchange rate fluctuations are one such phenomenon. The latter theory was given by Branson et al. (1977), and postulates that stock prices can cause exchange rate movements via capital account transactions. When foreign/domestic investors move funds from offshore securities into domestic securities, this buying and selling of domestic securities in foreign currencies in response to stock price movements indicates that stock price movements cause exchange rate movements.

Kim (2003) explains the influence of exchange rate changes on the changes in the behaviour of stock market prices; the underlying assumption is that corporate earnings fluctuate to changes in exchange rate. When a domestic currency appreciates, the importers buy goods/services by exchanging domestic currency by offering less domestic currency for foreign currency, hence reducing the cost of imports. Importers can sell these goods/services for the same selling price as before and thus making abnormal profits that will positively impact the stock prices of the company. On the contrary, when the domestic currency depreciates, importers will have to pay more of domestic currency in exchange for foreign currency, thereby increasing the cost of import. When importers sell these goods/services at the same selling price, profits decrease and stock prices go down. Thus, changes in foreign exchange rate cause changes in the cost and revenues of the firm with an initial impact on profits and then on stock prices (Wang, M-L. et al., 2010). This shows that there exists a positive relationship between the two markets. The markets also share a negative relationship: when exchange rate depreciates, the stock market attracts more foreign investment into the country, thereby influencing the stock prices to move up. When exchange rate appreciates, foreign

investors sell off their investments in stock markets thereby leading a decrease in the stock price index.

Foreign Exchange Market also impacts the commodity market by affecting the prices of commodities traded internationally (Keyfitz, R., 2004). A change in the country's exchange rate affects the commodities traded, which in turn affects the demand and supply of that country and the world at large, thus disturbing the global equilibrium.

Commodities are an alternative source of investment for investors to diversify and manage their portfolios. There is a debate on the relationship between stock market prices and commodity prices. Stock and commodity markets share a time varying relation. However, there is no clear-cut conclusion on their relationship as said by Vivian, A. and Wohar, M., (2012). Results, as shown by Creti, A. et al. (2013), indicate that there exists a time-varying high volatility between commodity and stock markets. Investors diversify their portfolios by investing in both commodity and equity markets. Strong stock market values lead to higher commodity prices as an increase in the stock market indicates economic growth and thereby increased demand for raw materials. On the contrary, a decline in stock prices could indicate a recession in the economy thereby leading to negative returns for commodities. The two asset classes need not always move together. As stock prices decline, commodity investments could make profits, one of the reasons being the varying response of financial institutions to stock price movements. If the commodity market starts declining, the financial institutions will liquidate their position in the stock market so as to raise cash to buy in the commodity market. Buyuksahin, B. et al. (2008) attribute a number of reasons for the decline in the growth rate of investment by financial institutions in the commodity market. Hence, the study tries to understand the dynamic long-run equilibrium relationship among stock market, foreign exchange market and commodity market.

1.1.1 VOLATILITY STUDY

Volatility in finance is the degree of change in the prices or returns of financial markets. This change could be when prices/returns move higher or lower and how widely they swing. There are five different types of volatility[1]

1.1.1.1. Price Volatility: Wide changes in demand and supply by various factors cause price volatility. The three main factors that affect price changes are seasonality, weather and emotions. Based on the season the demand for anything may go up or down, for e.g. during a wedding season or festival, the demand for gold rises, thereby increasing the price of gold, while at other times, the price of gold either falls or remains unchanged.

In case of weather, prices either increase or decrease. For e.g. agricultural output is linked to its price; when demand for output is more than supply (a case where weather has affected the agricultural output adversely), the price increases, and in case when supply is more than demand (a case where weather is favourable and doesn't affect the output),the price either remains the same or decreases. This third factor affecting the price change is the emotions of traders. When traders fear, they aggravate the volatility of whatever they are trading in.

1.1.1.2. Stock Volatility: The prices of stocks being highly volatile, makes them a more risky investment. This unpredictability & uncertainty makes investors demand a higher return for higher risks undertaken. Higher returns could be achieved either through a dramatic increase in stock prices and earnings or through a pay out of higher dividends to investors.

[1] (https://www.thebalance.com/volatility-definition-and-types-3305968)

1.1.1.3. Historical Volatility: It is nothing but how much volatility an investment or stock has had in the last 12 months. If the investment or stock has had moved over a larger bandwidth, then it is predicted that it is highly volatile. Thus, an investor needs to check the historical volatility of an investment or stock before investing. Highly volatile stocks or investments are a less attractive investment option over less volatile ones. Hence, an investor would have to wait longer to sell an investment or stock at a profitable price. With highly volatile stock, the investor would have to wait for a pretty long time, when the stock goes much lower, as the situation could get unpredictable.

1.1.1.4. Implied Volatility (market's current assumed volatility): It depicts the amount of volatility the options traders believe the stock will have in the future. By looking at the varying option prices, investors can find out the implied volatility of that stock. That is, if option prices increase, it means that there is a rise in implied volatility, all other factors being the same.

1.1.1.5. Market Volatility: It is the price change in any financial market (including stock, foreign exchange and commodities market). Increased volatility indicates that the market is either going up or down. Bullish trading raises the prices on the day of good news and bearish trading drive prices down on the day of bad news. Volatility with respect to financial assets is the measure of its variability over time i.e. from its expected value. When asset prices/returns fluctuate over a period of time, they exhibit serial correlation in the variance, and a direct consequence of this phenomenon is the volatility clustering. As given by Fama (1965), volatility clustering wherein "large changes tend to be followed by large changes of either sign, and small changes tend to be followed by small changes." The study tries to examine not just integration among the markets, but also volatility spillover among the said financial markets, forecasting the volatility of financial market returns.

1.1.2 VOLATILITY SPILLOVER

Engle et al. (1990) gave the concept of volatility spillover which laid the foundation of "own" and "cross" market spillovers. The concept of own spillover states that current volatility of a market is due to the past volatility of the same market. Whereas, cross-spillover states that, current volatility of a market is influenced by the past volatility of the same market and past volatility from other markets. Thus, spillover includes both "own" and "cross" spillover concepts. Financial markets are mostly affected by their "own" past volatility, but it is not the same in case of "cross" past volatility. When the market is integrated, they can individually get influenced by news and shocks originating from each other's economic, political, social, legal and environmental scenarios. They may also be linked to trade and commerce activities. This indicates the presence of volatility spillover among the markets when they are integrated. However, when the markets are not fully integrated, they show spillover effects during the financial crisis (Thesis). Globalization and integration among financial markets led to the analysis of spillover effects and is a continuous issue of research since then.

The volatility flows among the markets have an impact on the risk and return management process, which is of concern to both regulators and investors. Increased integration among markets reduces the expected gains through diversification. The volatility linkage among the markets arises from two sources (Fleming, J. et al. 1998); one is the common information affecting the markets individually and the other is the information spillover among the markets on account of cross-market hedging activities taken up by investors. This understanding of the inter-market information flow leads to better financial decisions such as risk management, financial assets pricing and portfolio selection in an increasingly global financial market. The increase in volatility linkages not only affects the portfolio's risk and returns but also the flow of funds among the

financial markets (domestically and/or internationally). Thus, one of the consequences of this increased volume of transactions is the increase in volatility linkages.

Movements of financial markets are not only affected by volatility spillovers among/from other financial markets, but also due to many factors, such as macro and microeconomic variables. These factors can be a signal to market participants to expect higher or lower return from investments.

1.1.3 MACROECONOMIC VARIABLES

These variables control the macro-economy and help understand the state of the economy as a whole at a point in time. Macroeconomic variables are indicators of current trends in the economy, with some economists using these variables to predict the future status of an economy based on current indicators. These indicators play a key role in impacting the financial market behaviour by influencing investor decision-making on their investments & risk management through diversification. The study tries to analyse the impact of scheduled macroeconomic variables announcement on the conditional variance of stock market, commodity market and foreign exchange market. The investors prior to any scheduled announcement mostly behave irrationally thereby increasing the volatility in respective markets. But soon after the announcement, if the information contained in the variables meets the expectations of the investors, it reduces the volatility in the market. On the contrary, if the news contained in the variables on the date of the announcement is not expected by the investors then the volatility in the respective markets will increase further. Hence, in general, if any macroeconomic variables are announced, the volatility of the financial markets tends to increase prior to the announcement and reduce after the announcement. The following scheduled macroeconomic variables are considered for the study:-

1.1.1.1. Index of Industrial Production: IIP is a composite indicator of short-term changes in the production volume of a basket of industrial products in a given period with respect to chosen base period. It also indicates short-term industrial growth until the results from Annual Survey of Industries and National Accounts Statistics are available. In the base year 1937, the Index of Industrial production under the Ministry of Commerce and Industry was first released by the office of the Economic Adviser. The Central Statistics Office (CSO) started compiling and releasing IIP on monthly basis since then. Presently, it is computed as the weighted average of production related to all the industrial activities. IIP uses 2004-05 as the base year for current calculations and data for the same was compiled from raw data received from 15 different source agencies: (i) Department of Industrial Policy and Promotion; (ii) Indian Bureau of Mines; (iii) Central Electricity Authority; (iv) Joint Plant Committee, Ministry of steel; (v) Ministry of Petroleum & Natural Gas, (vi) Office of Textile Commissioner; (vii) Department of Chemical and Petrochemicals; (viii) Directorate of Sugar and Vegetable oils; (ix) Department of Fertilizers; (x) Tea Board; (xi) Office of Jute Commissioner (xii) Office of Coal Controller (xiii) Railway Board; (xiv) Office of Salt Commission and (xv) Coffee Board.

An increase (decrease) in the value of Industrial Production Index would indicate an increase (decrease) in the manufacturing sector signalling a growth (fall in growth rate) in the industrial activity. An increase in IIP would have a positive impact on the financial markets under study i.e. stock market, commodity market and foreign exchange market. An increase in IIP indicates an increase in production which would not only encourage more exports (subject to international demand) but also indicates a growing economy that would attract investments from overseas, leading to an appreciation of the Indian Rupee (demand for the Indian Rupee). This appreciation of the Indian Rupee

would make imports cheaper for industries, thereby reducing the cost of production, resulting in a rise in profits. In addition to this, an increase in IIP would lead to a rise in profits for most industries, thereby driving the stock prices up. Besides, it would also lead to an increase in the demand for raw materials allowing the commodity prices to rise. These observations/relationships are maintained by keeping other macro-micro-economic factors constant.

1.1.1.2. Gross Domestic Product (GDP): The Gross Domestic Product (GDP) is the value of economic activities carried out within a country. GDP may be defined as the sum total of prices or market values of all the fiscal goods and services produced within an economy during a period of time. Every year in India, quarterly data of GDP is released with a lag of two months beginning from the last working day of the quarter. Calculation of Indian GDP follows two different methods: one is based on the economic activity (at factor cost), and the other is based on expenditure (at market prices). The calculations are further made to arrive at normal GDP values (using current market price) and at real GDP values (inflation adjusted). Among all these four values the most followed and reported figure is the GDP at factor cost values. This value of GDP at factor cost is calculated by gathering the data on net change in the value of economic activities for each sector during a specific period. The industries considered in calculating this cost are (i) Agriculture (ii) Mining and quarrying (iii) Manufacturing (iv) Construction (v) Electricity, Gas and Water supply (vi) Trade, Hotel, Transport and Communication (vii) Financing, Insurance, Real estate and business services (viii) Community, Social and personal services.

Increased value of GDP indicates the growth of an economy, which instils positive expectations in the minds of investors. Hence, on the announcement of an

upward swing in the GDP rate, the volatility of markets reduces, though prior to the announcement, markets behave irrationally, with heightened volatility, since the investors are not sure about the information content of GDP announcement.

1.1.1.3. Fiscal Deficit: It is the difference between the government's total expenditure and sum of revenue receipts and non-debt capital receipts, indicating the debt requirements by the government. Borrowings do not form a part of receipts while calculating the total revenue. This gap between expenditure and revenue is bridged through borrowings from the central bank or from capital markets by issuing various instruments like treasury bills, bonds etc. Fiscal deficit also acts as one of the major contributors to inflation. The government may also borrow from overseas to finance the debt, but too much of it would lead to the debt crisis and extensive domestic borrowing may lead to higher interest rates making it difficult for the domestic private sector companies to access funds that would result in "crowding out" of private investments. Fiscal Deficit = (Revenue Expenditure – Revenue Receipts) + Capital Expenditure – (Recoveries of loans + other receipts).

Increasing fiscal deficit most of the time indicates unplanned expenditure by the government; it may also be due to money injected into the economy to manage the money supply and restore confidence among the investors during the crisis period. Hence, an increase in the fiscal deficit would create volatility in the markets due to investors' (domestic and international) fear of "crowding out" effect in the private sector.

1.1.1.4. Inflation: Inflation is where an economy is facing increasing prices of goods and services combined with fall in the value of money. It is the condition where money supply exceeds the production of goods and services in an economy. Inflation is of two types (i) Cost-Push Inflation – wherein the prices of goods and services rise due

to the increased cost of inputs. (ii) Demand Pull Inflation – The rise in the prices of goods and services is due to an increase in the demand ever the supply for goods and services. The general price index which is used as the measurement of inflation measures the changes in the average prices of goods and services. The index of the base year is assumed to be 100 for the calculation of the current price index. If the current year index goes below 100 it indicates deflation and above 100 indicates the state of inflation.

The value of money is negatively correlated with inflation. In India, there are two indices that are used to measure inflation, (i) Wholesale Price Index (WPI), and Consumer Price Index (CPI). WPI was used as the main indicator of inflation in the economy till April 2014 and after that RBI adopted CPI as the main indicator of inflation. The wholesale price index measures the price of a basket of wholesale goods produced within an economy. It consists of 697 items in a basket which are divided into three broad groups (i) Manufactured products (65% of total weight), (ii) Primary items like food grains etc. (20.1% of total weight) and (iii) Fuel and power (14.9% of total weight). The base year for calculation of WPI is 2004-05. On the contrary, consumer price index measures the price changes at the retail level of a basket of commodities and services. It consists of 260 goods including a few services, the data of prices of sample goods and services are collected monthly by Central Statistical Office (CSO), Ministry of Statistics and Programme Implementation and if any change is noted. The base year for computation of CPI is 2012 which was changed from 2010 in January 2015.An increase in the rate of inflation would have a negative impact on stock market prices by impacting the real rate of return in the volatility of the stock market on account of bad news contained in the announcement. Likewise rise in the inflation rate calls for an increase in the interest rate by the RBI, to control the consumer spending and not allow the economy to enter in the state of hyperinflation. This increase in the interest rates would attract

investments from overseas then creating demand for Indian rupee (appreciation) and vice versa if interest rates were cut. Hence it indicates a negative relationship between inflation and exchange rate. On the contrary, a rise in the inflation rate suggests investing in commodities to control the inflation. Thus leading to the creation of volatility in the commodity market when the inflation rate is rising (news/information contained in the announcement of the inflation rate is negative). When the information content in the announcement of inflation rate is negative, it creates volatility in the markets.

1.1.1.5. Monetary Policy of RBI: It is the process done by the Central Bank of the country to control the money supply in the economy. If the money supply is not controlled and left to behave on its own, it will have adverse effects on the savings, investments, inflation and growth of the economy. To do so, RBI (Central Bank of India) use various instruments such as Repo rate, Reverse Repo rate, SLR, CRR and Bank rate to achieve its purpose. When the consumer spending increases RBI increases the bank rate, which affects the returns as the cost of borrowing increases and also affects the discount rate. Thus, having a negative relationship with the stock market and foreign exchange rate (increases the volatility when rates are increased). However, monetary policy would impact commodity prices through inflation and economic growth. Hence an increase in the borrowing rate affects inflation (cut down) thereby causing commodity prices to reduce. But the effect of monetary policy on commodity prices is quite limited rather it affects mostly stock and foreign exchange markets volatility.

1.1.1.6. Balance of Trade: It is the gap between country's imports and exports for a given period of time. It is used as a measure of relative strength of the economy by economists. If a country has a trade deficit it indicates, the total value of imports exceeds the total value of exports. The trade deficit is an indication of higher demand for foreign

currency than domestic currency, thus representing the outflow of domestic currency to foreign countries. On the contrary, if a country has a trade surplus it indicates that the total value of exports is more than the total value of imports. The trade surplus is an indication of higher demand for domestic currency and represents the inflow of domestic currency from foreign countries. The balance of trade value creates volatility in the foreign exchange market and thereby affecting the stock market in the country. Higher imports than exports create demand for foreign currency and allowing the domestic currency to depreciate; due to this the cost of imports would increase of the companies and get reflected in its profits and future cash flows. This affects the sentiments of investors and thus allowing the stock prices to fall. Trade deficit to a certain extent is desirable but if this deficit goes on increasing it would generate high volatility in both the stock market and foreign exchange market. Balance of trade doesn't have a direct impact on the commodity market of the country, it affects commodity market through inflation rate, also in a few cases investors/market participants would take future positions (long or short positions) to take advantage of increase/decrease in commodity prices that are internationally traded (Metals, energy etc).

1.2 LITERATURE REVIEW

Golub, (1983): The paper examines relationship between foreign exchange rate and oil prices, emphasizing on current and capital account of balance of payments. In 1973-74 the appreciation in dollar was due to unexpected price rise of oil and then depreciated in 1979 due to oil price rises. The main reason for demand in oil price is the USA's strong dependence on OPEC oil.

Cutler, D. M. et al. (1988): Vector Auto Regression measures the impact of macro-economic performance on stock market returns, and results suggest that these news

account for one fifth of variations in stock market fluctuations. They reveal that major movements in stock market prices are on the non-announcement days. This creates a doubt on the view that stock market prices move due to the news about discount rates and future cash flows.

Akgiray (1989): The article presents new findings about the temporal behaviour of stock market returns using two models – ARCH & GARCH. They try to model the conditional heteroskedasticity present in the time series of stock market returns. Various out-of-sample forecasts of monthly return variances are generated &statistically compared. Results indicated forecasts based on GARCH model are found to be superior.

Sephton (1992): examined data of three agricultural commodities prices in Canada and macro-economic news to determine whether or not commodity price inflation is due to information included in macro-economic variables (exchange rate). Using Johansen co-integration and Granger causality tests, results show that currency depreciation leads to commodity price inflation. This would allow the Central Bank of Canada to reduce general price inflation by influencing commodity price inflation.

Karolyi, (1995): examined volatility and return dynamics for stocks traded on the New York & Toronto stock exchanges using VAR, Univariate GARCH and BEKK and CC bivariate GARCH models. The cross market patterns in S&P500 & TSE300 returns illustrate that volatilities have changed over time. After 1980s, the magnitude of shocks originating in New York had a diminishing impact on subsequent TSE 300 returns. Study also tried to exploit the fact that many Canadian stocks inter-list on US exchanges to explore the importance of different types of linkages between markets that of inter-listed and non-inter-listed stocks. The impact of S&P500 stock return innovations on portfolios of inter-listed versus non-inter-listed TSE300 stocks is distinctly different and the

magnitude and persistence of S&P500 shocks are greater for subsequent returns of non-inter-listed shocks.

Bollerslev, T. et al. (1998): Using an annual sample of 5 min returns, the study provides a detailed characterization of volatility in Deutsche Mark to the Dollar in the foreign exchange market. The paper tries to capture the intra-day trading activity patterns, macroeconomic announcements and persistence of volatility. Results reveal that announcement effects are short-lived but prevalent at the highest frequencies. High frequency returns contain broadly valuable information for the measurement of volatility at the daily level, and also reveal that the high frequency return dynamics showcase long memory features.

Ng, (2000): examined the magnitude and changing nature of volatility spillovers from Japan & US to six Pacific-Basin equity markets. This behaviour and sources of volatility is critical for pricing domestic securities, asset allocation decisions and hedging strategy by means of ADC Model. ADC model nests four popular multivariate GARCH models, viz. VECH, BEKK, CCC and Factor ARCH model. The bi-variate GARCH model analyses joint processes governing the returns for the Tokyo Stock Exchange and S&P500 indices. Inference from the model discloses importance of regional and world market factors are influenced by important liberalization events. The changes in Pacific-Basin market volatility captured by the regional & world factors are generally small and in four out of six Pacific-basin countries, Japanese and US stocks together account for less than 10% weekly variations in returns.

Goundar, (2002): analysed inter linkages among foreign exchange markets in the Asian region using Johansen co-integration technique in the light of East Asian currency crisis of 1997-98. Asian countries considered under the study are Hong Kong, Indonesia,

Malaysia, Philippiness and Thailand. The study found presence of inter-linkages between exchange rate markets of these economies due to heavy cross border flows in goods and assets of the five countries.

Ledoit, O. et al. (2003): estimated the conditional covariance matrices. As the covariance matrix is an essential ingredient in risk management, portfolio selection & tests of asset pricing models. The usual way of estimating conditional covariance matrix is to compute maximum likelihood of estimates of parameters from observations of all the variables in the vector. The study compares the performance of several multivariate GARCH (1,1) covariance estimators using historical stock return data.

Simpson, (2002): aimed at studying the relationship between Australian-US exchange rate & commodity index prices. The study uses co-integration test, causality and regression analysis for a period from 1986 to 2001. Results indicated causality running from commodity price index to exchange rate and concluded that, foreign exchange market participants may use commodity price index info sensibly to alter their exchange rate expectations in the short run.

Protopapadakis (2002): Using GARCH (1,1) model, where 17 macro-economic announcements impact the equity daily returns and its conditional variance. Among these 17 announcement series, 6 were found to have significant impact, namely, CPI, PPI, Monetary aggregate, Balance of Trade, Employment report and Housing starts. The study also revealed negative correlation between Inflation and money growth.

Alaganar, V. T. (2002): the information flow between dually listed Australian & US stocks & stock indices were examined using bivariate GARCH model. Estimates indicated unidirectional flow of information from US stock market to Australian stock

market both with stock indices and dually listed stocks. Thus suggesting the influence of US is more prominent on Australian stocks.

Caceres (2003): tries to explore the linkage dynamics between foreign exchange markets by means of a multivariate regression model. The paper summarizes that such rates of Gautemala and El Salvador have time varying variance with asymmetric effects, in the sense that depreciation produce higher increase in the volatility of the variance than appreciations. It also indicated the convenience of designing multilateral monitoring mechanisms that can be useful to prevent crises and their spillover effects.

Miyakoshi (2003): investigated volatility spillovers from US and Japan onto seven Asian equity markets. The Bi-variate EGARCH model for US and Japan and Asian markets revealed that US has influenced the returns of Asian markets whereas Japan has influenced the volatility of Asian markets more than US. Also there exists an adverse influence of volatility of Asian markets on the Japanese market.

Andersen, T. G., et al. (2003): tries to analyse the impact of "news"(difference between macroeconomic expectations and macroeconomic realizations) on the US Dollar spot exchange rates for a period of 06 years using regression equation. The study uses a weighted least-square procedure, wherein firstly, a simple regression model is run to estimate conditional mean, and then from regression residuals, a weighted least-square procedure is performed. Results indicate conditional mean jumps on account of announcement surprises, thus suggesting the linkage dynamics between exchange rate and fundamentals. These linkages also include timing and sign effects of announcements. The sign effects of announcements suggest that markets react in an asymmetries way to any news realized. Bad news has a greater impact than good news.

Green, T. C. (2004): analysed the impact of trading during macro-economic announcements on bond prices in US markets. Study uses MMR model that allows for order flow to be auto correlated. Results indicate significant increase in the informational role of trading following economic announcement, thus suggesting the level of info asymmetry in the Government bond market on account of release of public information. Due to the surprise factor in the announcement and precision of public information and the informational role of trading is greater after announcement date. Informational role of trading is nothing but when few market participants have access to private info about the value of an asset, their traders will reveal info to the market. When markets are in equilibrium, the sensitivity of prices to the order flow will depend on the prevailing level of info asymmetry.

Aroskar, R. et al., (2004): Studies the impact on foreign exchange market of European Financial crisis, 1992 by dividing the study period into pre crisis, crisis and post crisis periods. Data is for a period from Jan 1990 to Dec 1999 study tests for Foreign exchange market efficiency using co-integration tests. Presence of co-integration can be interpreted as market inefficiency & / or the existence of risk premium and absence implies market efficiency. Study concludes that, the possible presence of risk premium and market inefficiency has made the relationship the European Currency are not stable during the pre-crisis and the post crisis periods.

Baele, L. (2005): investigated the extent to which globalization & regional integration lead to increasing equity market interdependence using regime switching model (allows the shock sensitivities to change overtime). Thus, by trying to quantify magnitude & time varying nature of volatility spillovers from the aggregate EU (western region) and US market to 13 local European equity markets, the study demonstrates that increased trade

integration, equity market development, and low inflation contribute to the increase in EU shock spillover intensity. Along with, the study also finds evidence for contagion from the US market to a number of local European equity markets during periods of high world market volatility.

Badrinath, H. R. and Apte, P. G. (2005): analysed the integration among foreign exchange market, stock market and call money market in India through volatility spillovers using multivariate EGARCH models. The study concluded the presence of volatility spillovers across these markets, suggesting that each of the financial markets are sensitive to news originating in the other two markets as a result of contagion effects.

Yang, J. et al. (2003): examines the lead-lag relationship between futures trading activity and cash price volatility for major agricultural commodities. They employed Granger causality test for daily cash closing prices, daily future settlement prices, and total futures trading volume of corn, soya bean, sugar, wheat and cotton. Results of Granger causality test suggested unexpected increase in futures trading volume which causes an increase in cash price volatility. Also, it has been observed that there exists weak causal feedback between open interest and cash price volatility.These findings are consistent with the destabilizing effect of futures trading.

Thierry Anne, (2006): investigated cross-market linkages and interactions that would help to better manage international financial exposure by analysing the degree of price and volatility spillovers in a non-Gaussian conditional framework. Using multivariate GARCH model that is Copula based multivariate model with asymmetric t-margins suggested, including non-linear functions as in the case of copula function, parameter with dependence characteristics incorporates unexpected shocks in each country.

Yau, H-Y. and Nieh, C-C. (2006): studied the inter relationship among stock market & exchange rate of Japan & Taiwan in the aftermath of the Asian crisis of 1997. A detailed investigation into short term causal relations & long term equilibrium relationship among the two financial assets – stock index of Japan & Taiwan & exchange rate applying Johansen's co-integration test among Granger's causality test. Results indicate that there exists no long run equilibrium relationship among stock prices of Japan & Taiwan and exchange rate of NTD/Yen. Also the results of GC test reveal that bi-directional causality existed among stock price index of Taiwan & Japan.

Malik, F. and Hammoudeh, S. (2007): uses multivariate GARCH model to simultaneously estimate the mean and conditional variance of daily returns in the oil market, and the US and the Gulf the equity markets. The study examined volatility transmission & stock among the oil market, US equity markets, and equity markets of Bahrain, Kuwait and Saudi Arabia, where results demonstrate significant volatility transmission among US and global oil markets and all the three Gulf equity markets receive volatility from oil markets. Also, news shocks in the US equity markets affect Gulf equity markets indirectly, indicating cross-market hedging and sharing of common information among the investors in the said markets under study.

Bhar, R. and Nikolava, B. (2007): attempts to study the degree of integration of the BRIC countries on a regional & global basis with a two stage GARCH in Mean approach. Results suggest that conditional mean returns and volatility of BRIC countries are influenced by world events. Whereas, regional trends have greater influence than the world trends in the equity price creation process for all BRIC Countries.

Morales, L., (2008): investigates the nature of volatility spillover between stock return and exchange rates in six Latin American Countries & one European economy. The

sample is divided into sub periods, prior to & after the introduction of the Euro. Using the EGARCH methodology to model volatility, results show that volatility of stocks returns affects the volatility of exchange rates. However, we do not find evidence of volatility transmission in the opposite direction.

Richards, N. D. et al. (2009): examines the interaction between stock prices and exchange rates in Australia, using Co-integration and Granger Causality for Australian-USD exchange rate, daily closing prices of All Ordinaries stock price index. Results provide evidence of a positive co-integrating relationship between these variables, with Granger causality found to run from stock prices to the exchange rate during the sample period.

Chanthapun, (2010): investigated inter-connections among foreign exchange, commodity and equity markets of commodity exporting countries (Australia, New-Zealand and Canada) from 1980-2008, using latent factor model and multi-directional spillovers. Evidences of bidirectional causality were found between commodity and foreign exchange markets of the three countries. It suggested the inter-connections among foreign exchange market and stock market of commodity-exporting countries. The results suggested a negative relationship between foreign exchange market & stock market in commodity-exporting countries, suggested by the "uncovered equity party" condition on the portfolio rebalancing hypothesis.

According to Kedarnath, M. and Mishra, R. K. (2010): transmission of information among the markets has gained importance among the researchers due to interdependencies among various financial markets across the world. The paper investigates first & second moment interactions among the Indian equity market, both, during trading and non-trading hours with 12 other Asian countries. Using basic GARCH (1,1) model, the study suggested that most of the information gets transmitted among the

markets without much delay, whereas some amount of information still remains & can be successfully transmitted as soon as the market opens next day.

Creti, A. et al. (2013): investigates the relationship between commodity and stock markets. Dynamic Conditional Correlation (DCC) GARCH is used in analysing daily spot price of twenty five commodities and daily closing price of stock index (S&P500). The results show that the correlation between stock and commodities market has evolved over the period with high volatility.

Hussian, M. Y. M. et al. (2012): using a vector auto regression (VAR) model examined the relationship between oil price, exchange rate and Islamic stock market index of Malaysia. Stock market and exchange rate showed no significant relationship, whereas it shared a positive relationship with oil prices. Islamic stock market consisted mostly of gas and oil firms, therefore any increase in oil prices showed positive effect on stock prices, as investors too had positive expectation from economic performances and continuous capital flow during the times of increasing oil prices.

Bilal, A. R. (2013): examined the existence of long run relationship among gold prices, Bombay Stock Exchange (BSE) and Karachi Stock Exchange (KSE). Using Johansen's co-integration test, the study proved the non-existence of long run relationship between gold prices and KSE, whereas, on the contrary, thestudy proved the existence ofa long run relationship between gold prices and BSE. However, Granger causality test demonstrated existence of no causal relationship among gold prices, KSE and BSE stock indices.

Cetin, C. et al. (2013): studied the relationship between US & UK major asset classes to determine the role of these variables in acting as a safe haven and to seek evidence on dependence among these asset classes during extreme price movements. The study

revealed that gold can be considered a safe haven against exchange rates in both countries.

Hamori, (2013): investigated interactions among the stock, commodity & foreign exchange markets of Northeast Asian countries (Japan, South Korea & Taiwan) using AR-EGARCH model. Results indicated that during the crisis period, Japanese financial markets showed a high degree of interaction, and the South Korean foreign exchange markets showed low degree of integration. The Taiwan foreign exchange market, on the other hand, showed no interactions among them during the crisis period, suggesting optimisation of investment portfolios of investors & portfolio managers by reducing the volatility risk during crisis periods with due consideration of other financial markets variance influence.

Patnaik, A. (2013): attempts to estimate MV-GARCH model to measure the volatility spillover across the Indian rupee vis. a vis. four prominent foreign currencies. Using DCC-GARCH model, a multivariate GARCH model is useful in learning multi asset volatility models, especially useful in studying volatility spillovers.

Seong, L. M. (2013): examined relationship among exchange rates & Malaysian stock market using Engle-Granger co-integration and error correction model and causality test in determining long run relationships, speed of adjustment and causality between all the variables. In line with Goods Market Approach by Dornbusch & Fischer, (1980),the study proved the presence of significant negative short run & long run relationships between exchange rate and the Malaysian stock market. This indicated that exchange rate depreciation has a positive effect on stock market. The Granger Causality test results consistent with Portfolio Approach also indicate the existence of bi-directional causality between the Malaysian stock market and exchange rate.

Jakpar, S. et al. (2013), investigated the co-movement of stock market volatility between China & ASEAN-5countries (Singapore, Thailand, Indonesia, Malaysia, Philipines) using Johansen's co integration & Granger causality test. Results indicate co-movement of stock market volatility between China& ASEAN-5 also bi-directional causality between China & Indonesia, China and Thailand & China & Singapore. Whereas Granger Causality test suggested, there existed no causality between China & Malaysia and China and Philippines.

Ben Omrane, W. and Hafner, C. M. (2013): using a multivariate volatility model, analysed the direct and indirect effects of macro-economic announcements on volatility spillovers across foreign exchange rates of Euro, Pound and Yen quoted per US Dollar. For the said purpose, scheduled and unscheduled news announcements arising from US, UK, European and Japanese economic performance were considered. Results indicated that more than 50% of total news effect on Pound and Yen is due to volatility transmission from US Dollar and Euro.

Savor, P. and Wilson, M. (2013): examined the response of stock market returns to the scheduled macro-economic news announcements using. Using the Panel Regression model, the results demonstrate a link between asset returns and scheduled macroeconomic risk. Investors expect higher returns on risky assets for bearing macroeconomic news risk as compensation, while on non-announcement days, the risk premium on assets is low.

Wang, Y. S. and Chueh Y. L. (2013): tried to analyse the short and long-run dynamics between gold price, interest rate, oil prices and US dollar. The study made use of threshold co-integration test to analyse long run equilibrium relationship and concluded that there existed a long term equilibrium relationship, implying investors cannot

diversify portfolio risks by pairing any two of these four variables, whereas in the short run, interest rates in the previous period have a negative impact on gold prices & positive impact on crude oil prices.

Teulon, F. et al. (2014): analysed the time varying integration of Singapore stock market with ASEAN-5 regional stock market (Indonesia, Malaysia, Thailand, Philippines & Singapore). By means of C-DCC-FIAPARCH parameters, theoutcomes show that integration degree varied widely over the period 1996-2011. This can be satisfactory explained by the level of trade openers & variations in the US term premium. One of the results suggest that diversification into more developed emerging markets does not produce as much substantial benefit as compared to the regional markets. It also indicated that Singapore is integrated into world markets like other Pacific Basin countries such as Taiwan, Korea & Indonesia. However, the degree of Singapore stock market segmentation changes overtime. In the recent period, the financial market has become less segmented as a result of liberalization and reforms.

Ozer-Imer, I. and Ozkan, I. (2014): conferred that crisis usually spreads from originating country to other countries. As the crisis results in co-movement of assets, co-movement becomes an essential component to study the impact of the crisis, finally influencing the financial decisions of investors and portfolio managers. It follows Geometric Brownian Motion to estimate points of change in volatilities which is the most widely used model for asset prices in finance, and estimates the strength of correlation among the currencies. The study found that correlations are time varying & follow different patterns during crisis. The correlations increase with onset of crisis, & continue to remain high while fluctuating until end of the crisis period. One important finding is that the correlation structure between the currencies does not change.

Mondal, L. (2014): examined the exchange rate volatility fluctuations post RBI intervention, where objective of intervention is to reduce undue fluctuations' in exchange rate. Estimates show that volatility spillover exists between Exchange rate and RBI's Foreign Exchange intervention through buying & selling of currencies. The lagged volatility of intervention has a positive impact on current volatility of exchange rate. Similarly, lagged volatility of exchange rate increases the current volatility of intervention. They also suggest that exchange rate volatility is sensitive to its own past shock in comparison to the shock of lagged intervention. Hence, RBI's intervention in volatility is more sensitive to the lagged volatility of exchange rate than to its own past volatility.

Jena, P. K. (2016): analysed the integration among domestic commodity index (all commodity index, energy index, agriculture index and metal index) and international commodity index (all commodity index, energy index, agriculture index and metal index). Using co-integration and vector error correction models, the study reveals no integrating relationship between domestic and international agricultural price index, whereas in case of other commodity index (all commodity index, energy index and metal index) there exists long run and short run relationship between domestic and international commodity price index.

Kaboro, J. et al. (2018): A panel data analysis was carried out to understand the effect of convergence in real GDP growth rate on exchange rate volatility of five East African commodity countries: Kenya, Uganda, Tanzania, Burundi and Rwanda for period from 2000-2016. The results reveal existence of long run relationship between exchange rate and explanatory variable. It also suggested that the explanatory variable had a significant negative effect on exchange rate volatility, which means that GDP growth rate

convergence among East African commodity countries reduces variability in the exchange rate.

Nijam, H.M. et al. (2018): examined the impact of macro-economic variables on stock market performance in Sri Lanka. The macro economic variables considered under the study are GDP, Inflation, Interest rate, Balance of Payment and Exchange Rate from 1980-2012. For empirical evidence ordinary least square is used to estimate the parameters for the model. The analysis indicates that macro-economic variables and the stock market index are significantly related. GDP shares a positive relationship with stock market, whereas Interest rate, Exchange rate and inflation rate share negative relationship with the market.

1.3 RESEARCH GAP AND IMPORTANCE OF THE STUDY

In the past years, various researchers in their study not only analysed linkage dynamics of various domestic asset classes (financial markets) with international asset classes (financial markets) but also examined the relationship among various asset classes domestically. Thus the main objective of the study is to empirically investigate the linkage dynamics among stock markets, commodity markets and foreign exchange markets in India.

Commodity markets that were basically considered only for pure physical trading in the past years have changed and have been considered as an investment option by investors since 2000. There are influxes of investors who are attracted to commodity markets purely as an investment option for hedging of risks, as they have gained rapid growth in liquidity (Vivian, A. and Wohar, M., 2012)

Commodity markets have also played a crucial role in influencing financial markets both domestically and internationally. This has been an active area of research

for many researchers in the area of financial economics especially for many researchers in the area of financial economics especially with individual commodities or a group of commodities. Hardly studies have considered analysing the linkages by taking commodity index into account rather than individual commodities or a group of commodities. Oil prices and gold prices that account for approximately 40% of the weight in the commodity index (MCX COMDEX) have gained much attention in the past decades. Oil prices are considered to be both determinant and predictor of stock returns (Driesprong, G. et al. 2008, Narayan and Sharma, 2011) whereas gold is considered to be a safe haven (Baur and Lucey, 2010, Baur and McDermott, 2010). Such an asset class offers investors an opportunity to protect their wealth in the event of negative market conditions. Hence the study considers taking into account the commodity price index as one of the asset classes in linkage dynamic analysis.

During and after the global financial crisis of 2008, the exchange rate was affected the most having an impact on the other asset classes (stock and commodity markets) in India. The fluctuations in the exchange rate were due to the news announcements in the US that had a profound impact on the US Dollars value and thereby on the Indian rupee. Moreover, the withdrawal of investments by foreign investors (especially foreign portfolio investors FPI / FIIs) created changes in exchange rate and stock market prices. Besides this, the rising crude oil prices placed a burden on Indian rupee and also increased inflation in the economy. All these events were the background that motivated in analysing the linkage dynamics among the stock market, commodity market and foreign exchange market.

To begin with, the first study tries to analyse integrating relationship among the markets as this allows examining if the prices of asset classes follow a similar pattern

over a long period of time. It helps the market participants in understanding how much different asset classes are related to each other. This study about integration is of great importance to investors, other market participants, academicians and researchers, as it is well known that if markets are highly integrated then diversification of investment to reduce risk across asset classes will not be advantageous. Rather timing the diversification among the asset classes based on the relationship pattern (i.e. positive or negative) and occurrence of various events (macroeconomic announcements, crisis periods etc), that have a profound impact on the markets would help the participants to take advantage through diversification by reducing the risk involved before diversifying the portfolio. Hence the study to analyse integration among the markets divides the study period into two parts: one prior to the global financial crisis of 2008 and the other is the post-crisis period. It has been observed that during the times of crisis the linkage dynamics between markets vary dramatically.

One of the main reasons for undertaking such studies is to analysethe impact of events happening in one market on the other markets. Secondly, the study expects the three markets (stock, commodity and foreign exchange markets) to be affected by some common news/information i.e. macroeconomic announcements. And lastly, the study expects the three markets to be influenced by volatility spillover on account of cross-market hedging activities.

Market price index returns reflect the expectations of investors about the future returns that would be affected by the volatilities in the market. Hence it is crucial for the market participants to identify the factors affecting the market volatilities and hence the future market price returns. Thus, the study tries to develop a model that captures volatility fluctuations in the market on account of some common information that enters

the economy. Also consequently study develops another model that captures market volatilities and spillovers caused by cross-market hedging activities. Fleming, J., (1998) developed a model that formalizes the relationship between information and volatility and suggested two sources that lead to volatility linkages. The first source is the common information, it affects more than one market simultaneously, for e.g. macroeconomic announcements of activities in the economy is the common information that creates volatility changes in the markets. The information encourages trading activities in the markets by the investors with changes in their speculative demands. On the other hand, the second source of volatility linkages is the information spillovers. They occur when the information affects one market and the investors in response react to this information causing changes in other markets activity by rebalancing their portfolios through cross-hedging. The spillover effects would be high across markets if investors could reap the benefits through cross-hedging by diversifying their portfolio and the cost of doing so should be lower than the benefits.

The study about volatility linkage is of great importance and needs to be taken into account by various market participants such as investors, policymakers and portfolio managers in their investment decisions. This is beneficial especially for formulating strategies to manage the risk involved in the portfolio of investments. This risk reduction achieved by shifting of funds from one market to another depends on the volatility linkages among them.

In other words, the study would help investors take an informed decision about shifting their investments across markets in order to avoid higher risk. If investors/market participants fail to take decisions related to investment diversification on account of strong volatility fluctuations, then they will have to face higher risk exposure, much same

as before shifting their investments. Hence financial market studies have gained enormous importance since the development of financial instruments, expansion in financial assets and changing trends in international capital privatization; as it has led to the creation of a large volume of international floating capital that has an impact on the financial stability of developing countries. This study contributes to the existing literature on investigating linkage dynamics among the stock market, commodity market and foreign exchange market in India in terms of integration, common information impacting the volatilities and the volatility link among the said markets.

1.4 OBJECTIVES OF THE STUDY

1.4.1 To examine the integration among the markets during pre and post-crisis of 2008.

1.4.2 To empirically examine the conditional variance behaviour of the markets in response to select scheduled macroeconomic announcements in India.

1.4.3 To investigate the volatility spillovers across the markets.

1.5 LIMITATIONS OF THE STUDY

1.5.1 Select scheduled macroeconomic variables were considered under the study

1.5.2 Model created convergence issues in usage of large data sets

1.5.3 Various economic events that occurred during the said time period was not considered due to convergence issues in running the model.

1.6 METHODOLOGY

1.6.1 UNIT ROOT TESTING:

One of the important properties of any time series process is whether it is stationary or not. If a time series process follows a probability distribution which is the same at every point in time, then the process is said to be stationary. A stationary process also necessitates that; the effects of any shock to a series must eventually die out. Variables

with a trend component in the series are the ones that are non-stationary in nature. Since variables with trend either grow or shrink over time, the mean of the distribution is not the same at all times. Any empirical work under study related to time series data assumes stationarity for underlying time series variables. This is important, as non-stationary time series can be studied only for the time period under consideration. As a result, it is not possible to generalize the outcome of the study to other time periods. Therefore, practically such time series (non-stationary) is invaluable for forecasting purpose. There is a special type of stochastic process (or time series) namely purely random, white noise process as it has Zero mean, constant variance & serially uncorrelated. To test whether the stochastic process is stationary or not, widely popular test named unit root test has been used by many practitioners from past several years.

$$y_{t-1} = \rho y_{t-1} + e_t \quad -1 \leq \rho \leq 1 \qquad \text{……..(1)}$$

In the above equation if ρ=1, then it is the case of unit root and the process becomes a Random Walk Model (also known as no stationary stochastic process).

From equation 1, y_{t-1} is subtracted from both the sides to obtain equation 2:

$$\Delta y_{t-1} = \partial y_{t-1} + \quad _t \qquad \text{……(2)}$$

Where ∂ and Δ are the first difference operator and ∂ = (ρ-1).

Practically equation 2 is estimated instead of equation 1 to test the null hypothesis of $\partial = 0$. If ∂=0, then ρ=1, that shows the existence of unit root – the time series is non-stationary. Hence, for the stochastic process to be stationary ρ must be less than 1. To test the same, Dickey and Fuller have computed τ (tau) statistic based on Monte Carlo simulations, which is also known as Dickey-Fuller (DF) test. While estimating Dickey-Fuller test it was assumed that error term e_t was uncorrelated. But when e_t are correlated Dickey and Fuller developed another test which is an

extension of Dickey-Fuller test known as "Augmented Dickey-Fuller (ADF) test. The ADF test estimates the following equation:

$$\Delta y_t = \beta_1 + \beta_2 t + \partial y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta y_{t-i} + \varepsilon_t$$

β_1 is a constant, β_2 is the trend coefficient, Δy_{t-i} is the summation of $\Delta y_{t-1} = (y_{t-1} - y_{t-2})$, $\Delta y_{t-2} = (y_{t-2} - y_{t-3})$, $\Delta y_{t-3} = (y_{t-3} - y_{t-4}) etc$ ..., where ε_t is a white noise error term and ∂ is on which the test is conducted.

The idea behind the inclusion of enough lagged difference terms in the equation is to see that ε_t (error term) is serially uncorrelated. Even in ADF test the hypothesis is $\partial = 0$, based on significance level, it is either accepted or rejected.

1.6.2 CO-INTEGRATION TEST:

In a univariate framework, non-stationarity series can be estimated by differencing. The idea was generalized for all non-stationary variables used under regression analysis once upon a time. However, it is not an appropriate way to treat non-stationary variables in a multivariate context, as these could be a possibility of a linear combination of integrated variables that are stationary, such variables are considered to be co-integrated. An equilibrium relationship among non-stationary variables suggests a linkage between their stochastic trends. Whereby, equilibrium relationship means the variables are unable to move independently of each other. When the trends of variables are linked, their dynamic paths share some relation to the current deviation from their equilibrium relationship. As per Engle and Granger, co-integration refers to variables that are integrated of the same order. However, it does not suggest that all integrated variables are co-integrated. Such lack of co-integration suggests no long-run equilibrium relationship among the variables, as they can move independently far from each other. In case of $y_t \; and \; z_t$ sequences where x_t is a random walk process and $\varepsilon_{yt} \; and \; \varepsilon_{zt}$ are

white noise, then $y_t \; and \; z_t$ both would be random walk plus white noise process. Though they are non-stationary, both sequences have the same stochastic trend, thus co-integrated such that their linear combination is stationary.

$$y_t = x_t + \varepsilon_{yt} z_t$$

$$= x_t + \varepsilon_{zt}$$

In the case of these sequences, those are random walk & white noise process, such that their stochastic trends are not the same. However, their linear combination is stationary, thus proving the three sequences are co-integrated.

As per the Johansen procedure (test co-integration among multiple variables) if there are "n" co-integrating vectors, then the "n" linear combination of the variables are stationary. This study employs three variables and the detailed technique is explained in the chapter.

1.6.3 VECTOR ERROR CORRECTION MECHANISM

In co-integration methodology, there is no much discussion on the time lags needed to achieve the equilibrium unless VECM is also estimated. For estimating dynamic models it is always best to estimate both long-run parameters and short-run dynamics jointly, as VECM can be used to combine short run-long run forecasts in a consistent fashion. The trends of co-integrated variables being linked, allow the dynamic paths of variables to bear some relation to the current deviation from the equilibrium relationship. This deviation from the equilibrium in the short run is captured through vector error correction mechanism. The methodology is explained in detail in the respective chapter.

1.6.4 GRANGER CAUSALITY IN VECM.

In simple case of two variables "x" and "y" the test of Granger Causality may be interpreted as when "x" granger causes "y" it means, "y" can be better predicted by

including past values of "x" and "y" both, rather than just past values of"y". But in a cointegrated system, we need to reinterpret Granger Causality. Thus testing for Granger Causality under VECM seems reasonably correct. It has been said that as VECM incorporates information as short-run dynamics about the co-integrated variables, tests conducted within this framework would be more powerful than their counterparts within a VAR model. Hence it can be said that in a VECM framework "x" granger causes "y" if lagged values of "x" enter "y" and "y" responds to the deviation from the long-run equilibrium. And thus it may be said that "y" is exogenous variable.

1.6.5 ARCH-LM TEST

The presence of volatility (i.e. time-varying variance) clusters, wherein large changes in variance tend to follow large changes and small changes in variance tend to follow small changes, can be modelled by ARCH-type models and this has been well documented in the finance literature. When a time series exhibits autoregressive conditional heteroskedasticity, then it can be said that series contains ARCH effects. To test the presence of ARCH effects in a series, Engle (1982) suggest an ARCH test which is a Lagrange Multiplier test popularly known as ARCH-LM test. The Null hypothesis says series has no ARCH effects, and in order to proceed with using ARCH/GARCH models, testing for the presence of ARCH effects is a must.

1.6.6 GARCH MODELS WITH EXTENSIONS

The assumption of constant variance (homoskedasticity) is unsuitable for many economic time series variables, as they demonstrate periods of large unusual volatility, followed by periods of relative tranquility. One way to model the variance is to introduce an independent variable that helps to predict the volatility, but a difficulty with this strategy is that it considers specific cause for the change in variance and the method

forces an independent variable to affect the mean of the series. Moreover, it necessitates a transformation of data such that the resulting series has a constant variance. Hence Engle (1982) using the ARCH model suggested that instead of using ad hoc variable choices to impact the series, it is possible to model the mean and variance of a series simultaneously using maximum likelihood techniques. In an ARCH (1) model the conditional variance follows a first order autoregression process. Bollerslev (1986) extended Engle's original work by developing a technique that allows the conditional variance to be an ARMA process. This generalized ARCH model is called as GARCH, where it allows for both autoregressive and moving average components in the heteroskedastic variance. At present econometricians have developed so many models of ARCH / GARCH to model conditional volatility that, researchers have to now know and reason out why they are selecting a particular model. This study employs four different GARCH models to model volatility and volatility spillover. In short, following are the models employed in the study, and in detail, they would be explained in respective chapters.

1.6.6.1 GARCH (1,1) Model:- This specification is the most popular form of conditional volatility where the financial data forces volatility shocks that are persistent.

$$y_t = \beta_1 + \beta_2 x_{2t} + \beta_3 x_{3t} + \beta_4 x_{4t} + \varepsilon_t \qquad \varepsilon_t \sim N(0, h_t)$$

$$h_t^2 = \omega + \sum_{i=t}^{q} \alpha_i \, \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \, h_{t-i}^2$$

In a GARCH (p,q) process it is necessary to ensure that α_1 and β_1 are non-negative. $h_t^2$is the conditional variance of a mean equation (may be a regression, AR(p), MA (q) or ARMA(p,q)) and can be modelled as shown in the above equation. The above conditional variance equation may be interpreted as an

ARMA model with autoregressive parameters h_t^2 and moving average parameters ε_t^2.

1.6.6.2 EGARCH – Exponential GARCH model:

The conditional variance of the above-mentioned GARCH (p,q) model only depends on the magnitude and not on the sign of ε_t. Many financial data (e.g. stock prices) exhibits the presence of leverage effects, where a standard GARCH (p,q) fails to report as it allows for the only symmetric effect of news. Hence an asymmetric GARCH model was introduced by Nelson (1990) to allow for leverage effects on conditional volatility known as the EGARCH model.

$$ln(h_t) = \alpha_0 + \alpha_1(\varepsilon_{t-1}/h_{t-1}^{0.5}) + \lambda_1\left|\varepsilon_{t-1}/h_{t-1}^{0.5}\right| + \beta_1 ln(h_{t-1})$$

The above-mentioned equation is called an exponential GARCH or EGARCH model. The equation of conditional variance is in log-linear form. Hence unlike in a GARCH (p,q) model, there is no restriction on the parameters to ensure non-negativity of the conditional variances. Instead of using values of ε_{t-1}^2 the EGARCH model uses the level of standardized value of ε_{t-1} (i.e.$\varepsilon_{t-1}/h_{t-1}^{0.5}$). Hence if $(\varepsilon_{t-1}/h_{t-1}^{0.5})$ is negative, then the effect of the shock on conditional variance is $(-\alpha_1 + \lambda_1)$ and thereby allowing it to rise. If $(\varepsilon_{t-1}/h_{t-1}^{0.5})$ is positive then the effect of the shock on conditional variance is $(\alpha_1 + \lambda_1)$ and thereby allowing it to fall.

1.6.6.3 TGARCH – Threshold GARCH

Another model that allows for the asymmetric effect of shock is the Threshold GARCH model popularly known as TGARCH model given by Glosten, Jaganathan and Runkle (1994). The model allows for the effects of good and bad news to have different effects on volatility. In a sense $\boldsymbol{\varepsilon_{t-1}}$=0 is a threshold such that shocks greater than the threshold have different effects than shocks below the threshold.

Following is the TGARCH process

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \lambda_1 d_{t-1} \varepsilon_{t-1}^2 + \beta_1 h_{t-1}$$

Where d_{t-1} is a dummy variable equal to one when $\varepsilon_{t-1} < 0$ and is equal to zero when $\varepsilon_{t-1} \geq 0$. Hence if $\lambda_1 > 0$, negative shocks will create larger effects on volatility than positive shocks and if $\lambda_1 < 0$ positive shocks will have larger effects on volatility than negative shocks. Thus, if the coefficient of λ_1 is statistically significant from zero, then it can be concluded that the data has a threshold effect.

1.6.6.4 BEKK – GARCH Model

While estimating the conditional volatility of data set with several variables, it often makes sense to estimate them simultaneously. Thus, estimating multivariate GARCH models (MV-GARCH) makes / sense, as they take advantage of the fact that the contemporaneous shocks to the variables can be correlated with each other. Additionally, MV-GARCH models allow for volatility spillovers among related variables wherein, shocks to one variables volatility might affect the volatility of other variables under the study. One of the very popular MV-GARCH models is the BEKK-GARCH model which is employed in this study to capture volatility spillover among the markets. This model was given by Baba, Engle, Kraft and Kroner (1990) and that's why popularly known as BEKK-GARCH model.

This model ensures positive values for conditional variances, by allowing the parameters that enter the model to take quadratic forms.

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}{}' A + B'H_{t-1}B$$

The detailed description of the equation is mentioned in the respective chapter. In general, the conditional variance (h_{ijt}) of a variable will depend on the squared residuals, cross-products of the residuals, and the conditional variances and co-variances of all variables in the data set. The model allows the shocks to the variance of one variable to spillover to the other variables. One difficulty with estimating this model is that of achieving the convergence.

1.6.7 LJUNG-BOX TESTS

The test used to check if the model estimated is adequate or not. Besides providing a good fit model, an estimated GARCH model needs to capture the dynamic facet of the mean model and variance model. Hence, the residuals estimated should to be serially uncorrelated and remaining conditional volatility should not be displayed. To test for the mean model, form Ljung-Box Q-Statistic of standardized residuals for the series, the study should be able to reject the null hypothesis the Q-Statistics for ‘n' lags is equal to zero. If fail to reject the null hypothesis, it shows the presence of serial correlation in the series and the mean model is not properly specified. Next in order to test for any remaining conditional volatility, form Ljung-Box Q-Statistics of squared standardized residuals. If there are no GARCH effects present in the residuals, then the study should be able to reject the null hypothesis that the values of Q-Statistics for ‘n' lags are equal to zero. Otherwise, it shows that there is a remaining GARCH effect in the model that is not captured. Once the study is able to reject the null hypothesis of Q-Statistics of standardized residuals and squared standardized residuals, we can conclude that the model estimated is a good fit model.

1.7 CHAPTERIZATION SCHEME

Chapter 01 focuses on introduction to the study, which comprises of understanding of volatility, volatility spillover, scheduled macroeconomic variables etc. Besides these, it also includes the literature review, research gap and importance of the study, objectives of the study, limitations, research methodology, and chapterization scheme.

Chapter 02 incorporates the discussions, results and analysis related to integration among, stock, commodity and foreign exchange markets during pre and post the global financial crisis of 2008 in India.

Chapter 03 elaborates on the impact of various scheduled macroeconomic variables announcement on the volatility of stock, commodity and foreign exchange markets. It analyses and discusses the investor sentiments on announcement of these scheduled macroeconomic variables announcement and their impact on the volatility of the markets.

Chapter 04 comprises of results and analysis pertaining to volatility spillovers across the stock, commodity and foreign exchange markets in India.

Chapter 05 summarizes the study, and is followed by analysis and conclusions along with policy implications of the study and scope for future research.

2 INTEGRATION OF MARKETS DURING PRE AND POST SUBPRIME CRISIS: EVIDENCE FROM INDIA.

2.1 INTRODUCTION

The opening of economies and increasing volatility among the financial markets in the post-liberalization period has resulted in an increasing interest in the analysis of integrated market relationships (Mensi et al., 2013). Investors and policymakers need to be careful about dependencies among the two financial markets (stock market and foreign exchange market) and commodity market, as, analysing these transmission channels will not only enhance the dexterity of policymakers in framing policies but also help in foreseeing the impact of their decisions.

In the past, the focal point of researchers and investors in their decision-making process was limited to stock, foreign exchange and money markets largely. However, in recent years, the commodity market has also gained tremendous importance as an investment avenue rather than just being a risk hedging instrument. This has led to a significant increase in the liquidity of commodity market (Vivian, A. and Wohar, M., 2012). In this regard, Driesprong et al. (2008) have discovered that prices of major commodities like oil to be the determinant as well as the predictor of stock prices. Further, Baur, D. and McDermott, T. (2010) have argued that gold can be considered as an asset holding its value even in unpleasant market conditions.

Besides these, the current account balance of the country also has an impact on the relationship between foreign exchange, stock and commodity markets. Most of the previous studies have followed three approaches while examining integrated market relationships. The first one is by examining the long run causal relationship among stock markets across various countries using techniques such as GARCH models, causality test

and co-integration test[2]. The second one is that of understanding the dynamics of the relationship among various financial markets in a single country, utilizing techniques such as GARCH and co-integration test.[3] Finally, panel analysis is used in investigating the linkage dynamics among various financial markets across various countries.[4] Expanding these studies further, the linkage dynamics are studied by including a factor of uncertainty.

Moreover, during times of turmoil, links between the asset classes severely alter and give less scope for diversification of portfolios. The empirical evidence of this study hinges on the phenomenon termed as "Paradox of Diversification".[5]

An attempt is made to analyse the integration among the said markets during the times of financial crunch. Nath, G. C. and Samantha, G. P. (2003), examined the condition of the integrated markets where the shocks in one market get reflected immediately in other markets. The transmission mechanism of monetary policy in such cases becomes smooth and speedy, thus making policy interventions more effective in bringing results in the desired direction within the specified time horizons. The development of highly integrated financial markets has always been the focus of modern policymakers. The subprime crisis of 2008, triggered by the collapse of Lehman Brothers, did not affect the US alone. Rather, the ripples of this crisis spread throughout the globe. India too could not insulate itself completely from the adverse effects of this

[2]Huanga (2000), Azman (2010) Sensoy (2014), were among the few who used the approach in their study.

[3] Badrinath (2005), Morales (2009), Kasman (2011), Wang (2013) and Turhan (2014) followed a different approach to understanding the relationship between the markets.

[4] Yau (2006) and Zhu (2014) have followed a combination of the two approaches.

[5](Authers, 2010): Where the investors buy on the assumption that the markets are not correlated, but ultimately leading to more correlation.

crisis. Economic growth of the country decelerated from 8.8% on an average during the previous five years to 6.7 per cent in 2008-09 (Bajpai, 2011).

Barely have any studies been conducted in understanding linkage dynamics among the said markets in India or internationally. In respect of this, the study tries to contribute to the prevailing works by using composite price index of stock and commodity market in analysing the co-integration relationship among stock market, commodity market and exchange rate in India at the time of crisis.

2.2 REVIEW OF RELATED LITERATURE:

The dynamic nexus among foreign exchange, stock and commodity markets has been well studied in previous studies, including the change in their linkages during the times of turmoil. The fact that turmoil of different origins has varied impact on the relationship among markets, it has attracted the interest of academicians and policymakers to probe into its detailed dynamics. In this regard, the literature talks about the European crisis (1992), the Asian Financial crisis (1997), the Subprime crisis (2008) and the European crisis (2010).

Aroskara et al. (2004) argued that the European crisis of 1992 created instability in the prevailing relationships among European currencies. They have divided the study period into pre-crisis, crisis, and post-crisis period. In the case of Asian crisis of 1997, Yang et al.(2003) studied the existence of relationships among the USA, Japan and ten Asian emerging stock markets and concluded that the markets strengthened during the crisis, and these markets have generally become more integrated in the aftermath of crisis than before the crisis period. Further, Khalid and Kawai (2003) identified the channels through which the Asian crisis spread among neighbouring countries. For this, data of financial market indicators i.e. foreign exchange rates, stock market prices and interest

rates from East Asian countries were collected. A VAR model was constructed, and Granger Causality test was applied to investigate linkages amongst various markets of different Asian countries. The results, however, suggested that the contagion in the financial market was not the key source for the financial crunch in the Asian region; rather, there were other factors responsible for the spread of the economic crisis. Click and Plummer(2005) tried to understand the integration among the stock markets in ASEAN countries after the Asian Crisis using co-integration test to investigate long-run relations. The concluding results suggested that as markets are not fully co-integrated, the benefits of portfolio diversification across the international markets are not eliminated but reduced. Choudhry and Peng (2007) empirically investigated the long-run association among the stock markets of the Far East countries around the Asian crisis, 1997 and also found that the USA and Japan had a significant influence on this relationship. Also, there are studies that have empirically analysed integration among interest rates (Guevara, J. et al., 2007) and stock markets (Babetskii, I. et al., 2007) among the European countries. Researchers have also investigated the existence of a relationship between a country's trade concentration and level of its financial integration using a GARCH-M model (Gibson, et al. 2008). Wang, et. al. (2010) and Zhu et al. (2014) studied the co-movement among the stock markets of Asia by applying Johansen co-integration test in pre and post-crisis period. Investigators concluded that no (negligible) co-movements existed in the pre-crisis period, but the linkage amongst them grew stronger since the crisis struck Asia in 1997, and in some cases, it even grew stronger after the crises.

Kassim, M. et al. (2009) using VAR methodology and Cheung, W. et al. (2010) using VAR model, Granger Causality test and Co-integration VECM analysed the linkage dynamics among the stock markets through the global crisis period of 2007-08,

and concluded that the connections among the markets developed stronger relations during the crisis and in the aftermath of crisis as well,therefore, resulting in lesser benefit arising from diversification of the portfolio. Dufrénot et al. (2011) conducted their study to explore whether the volatility changes in stock markets of Latin American countries (LACs) in the aftermath of 2007-08 crises could be attributed to the worsening environment of the US financial markets. The study utilizes the Markov-switching model for a period covering January 2004 to April 2009 and concluded that the financial stress from the US markets spread to the LACs stock markets creating volatility, particularly in Mexico. On the contrary, Xu and Hamori(2012), in their study on the impact of global financial crisis 2008 on linkage dynamics of the BRICS countries in the mean and variance of stock prices, revealed that the transmission effects from US market to BRIC markets weakened both in the mean and the variance after the 2008-09 crises. Similarly, (Guidi, et al. 2012) analysed linkage dynamics among Indian stock market and developed markets of Asia (Hong Kong, Japan and Singapore) by means of co-integration methodology, where results indicated an absence of strong linkages among the markets, providing potential benefits to the investors through portfolio diversification.

On the contrary, Sensoy and Sobaci (2014) investigated the relationship dynamics between major European countries and Turkey during the global financial crisis (Subprime crisis and Eurozone crisis) for the period from September 2004 to April 2013. The results proved the existence of integration between Turkey and major European economies in terms of risk perception, thereby restricting the diversification benefits for global investors.

Past studies empirically investigated linkage dynamics of stock markets, foreign exchange markets or interest rates or a combination of them regionally/ globally with various techniques to analyse the existence/ absence of relationship among them. Barely

have any studies on the global financial crisis of 2008 been conducted in India to analyse the relationship among price indices of stock, commodity and foreign exchange market. Therefore, this study aims at contributing to the existing literature by analysing the long-run and short-run relationship among the price index of stock markets, commodity market and foreign exchange market and a causal relationship among them, such that the results of the study could be beneficial to the investors/ portfolio managers in diversifying their portfolios.

2.3 METHODOLOGY

To analyse the dynamic inter-linkages between stock, commodity and the foreign exchange markets, the study makes use of daily closing prices of CNX NIFTY (stock price index), COMDEX (commodity price index) and a nominal exchange rate of the India Rupee v/s the US Dollar. The period of study is from 21stOctober, 2005 to 31st August, 2016. The sample has been further sub-divided into the pre-crisis period and post-crisis period, i.e. from 21stOctober, 2005 to 31st August, 2008 and from 1stSeptember, 2008 to 31stAugust, 2016, respectively.

The literature review provides evidence for the presence of some long-run relationship amongst non-stationary variables which require systematic treatment, and the same has been attempted here. The methodology carried out in the paper consists of three parts: Co-integration analysis, Vector Error Correction Mechanism and Granger Causality using VECM.

The first step entails the use of Augmented Dickey-Fuller test to check for stationarity and to detect the presence of unit roots in time series. This is in tune with the Johansen co-integration test, which demands that the series should be integrated of the same order.

Subsequently, Johansen co-integration (the λ_{trace} and λ_{max} statistic test) is applied to examine if any long-run equilibrium linkage exists amidst the non-stationary variables. Any equilibrium relationship among non-stationary variables implies that the variables must be linked and the linkage necessitates the variables to be co-integrated. The variable denoted are as follows: $'p_t'$ is the commodity price index, $'e_t'$ is the exchange rate and $'n_t'$ is the stock price index. Johansen and Juselius (1990) give the following general model:

$$x_t = \pi_1 x_{t-1} + \cdots + \pi_k x_{t-k} + \mu + e_t \qquad for\ t = 1, \ldots, T,$$

Here, vector x_t = ($p_{t,} e_{t,} n_t$), e_t are independent normal errors with mean zero and covariance matrix Λ, μ is an intercept vector. The co-integrating equation (1, 1, -1), is a linear combination of $e_t + n_t - p_t$ such that it is stationary. When the confirmation for co-integration is established, the rest of the work concerns estimating the error correction model. The disequilibrium in the long run relationship is examined using the speed of adjustment parameter applying Vector Error Correction Mechanism (VECM). Subsequently, based on the above general methodology, we estimate the following models in our study:

$$\Delta p_t = c_1 + \lambda_p(p_t - \beta_0 - \beta_1 e_t - \beta_2 n_t) + \sum a_{11}\,\Delta p_{t-i} + \sum a_{12}\,\Delta e_{t-i} + \sum a_{13}\,\Delta n_{t-i} + \varepsilon_{1t}$$

$$\Delta e_t = c_2 + \lambda_e(p_t - \beta_0 - \beta_1 e_t - \beta_2 n_t) + \sum a_{21}\,\Delta p_{t-i} + \sum a_{22}\,\Delta e_{t-i} + \sum a_{23}\,\Delta n_{t-i} + \varepsilon_{2t}$$

$$\Delta n_t = c_3 + \lambda_n(p_t - \beta_0 - \beta_1 e_t - \beta_2 n_t) + \sum a_{31}\,\Delta p_{t-i} + \sum a_{32}\,\Delta e_{t-i} + \sum a_{33}\,\Delta n_{t-i} + \varepsilon_{3t}$$

Where β_s (β_0, β_1 & β_2) are the long-run equilibrium relationship coefficients, λ_s are the measures of short-run responsiveness to the deviations from the above equilibrium long-run relationships i.e. the average speed of adjustment coefficients of p_t, e_t and n_t to their deviations from the above long-run equilibrium relationship, a_s, are the VAR response coefficients and e_s are the Gaussian errors.

Finally, causality tests on error correction model could help identify a structural model and determine whether the estimated model appears to be reasonable. To test for causality in a co-integrated environment, we cannot use standard F-test, as Granger Causality involves only stationary variables and co-integration is viewed as an indirect test of long-run causality (Enders, 2010). In multivariate environments, testing for long-run causality between two variables becomes problematic as it is impossible to tell which explanatory variable is causing the dependent variable through Error Correction term. Hence, the study uses Granger Causality test under the VECM environment, which includes differenced variables and not actual variables at levels that are non-stationary.

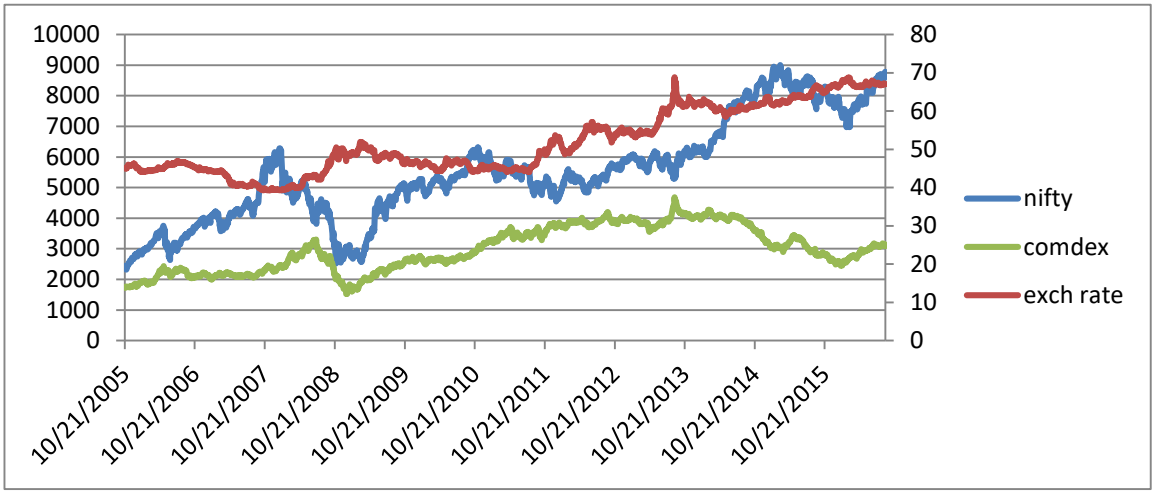
Furthermore, it should be noted that under VECM framework, the speed of adjustment parameters also signifies the temporal or long run causality among the variables; the short-run causality in this case can be understood by running block exogenity tests on the lagged endogenous variables employing standard F-test or χ^2-test[6].

[6] It is very necessary that the exogenity tests are conducted in the VECM specification which contains variables in first difference as the test statistic obtained from running similar tests on a non-stationary variables do not follow the conventional F and χ^2 distribution (Toda and Yamamoto,1995)

2.4 EMPIRICAL RESULS AND ANALYSIS

Figure 2.1 explains the period in which there was drastic fall in the price index of the stock market, commodity market and exchange rate, telling the date before which will be considered as pre-crisis and after as the post-crisis period.

Figure 2.1: Showing price index movements of Commodity market, Foreign exchange market and Stock market in India.



Source: NSE website, RBI website and MCX website for data

In the year 2008, the Indian stock market, the foreign exchange market and the commodity market witnessed a drastic change in the price trend as revealed. The effect of this crisis was positive at the start, as it brought more inflow of FIIs into the country, which made the people feel that emerging economies are insulated from the crisis and would act as an alternative engine of growth to the world economy. But the effect soon turned negative as the crisis spread to emerging economies. The subprime crisis affected India by affecting its Current Account and Capital Account. Its Current Account Deficit increased from 1.5 per cent of GDP in 2007-08 to 2.6 per cent of GDP in 2008-09. The Capital Account Surplus dropped from a record high of 9.3 per cent of GDP in 2007-08 to 0.9 per cent of GDP in 2008-09 due to the withdrawal of capital by FIIs from Indian financial markets. The impact of this crisis was felt in terms of reduction (fell to 4.34%

in 2008-09) in exports, a decline of industrial growth and employment (employment rate increased since 2002 but, fell in 2007-08 from 13% to 1%), depreciation of the rupee (by 21.2% against USD in 2008-09), downturn in stock returns and many other indicators.

Table 2.1: The Chow test

Break Point date	F-statistic
1st September 2018	243.535 (0.00)

The value in parenthesis indicates p-values

The graph (Fig: 2.1) and Chow test (Table 2.1) confirmed that 1st September, 2008 can be taken as a break point in apportioning the data sample into pre and post-crisis period. Taking the above results into consideration, we move towards formal testing of time series. To test the stationarity of time series variables, Augmented Dickey-Fuller test has been applied. The prerequisite before applying co-integration test is that variables should be integrated of order one, I(1), which requires the variables to be non-stationary at levels, but stationary at first difference.

Table 2.2: Unit Root Test for price index of the Commodity market, Foreign exchange market and Stock market

ADF test

Variable	**Pre – Crisis Period**		**Post – Crisis Period**	
	Levels	*First Difference*	*Levels*	*First Difference*
$\boldsymbol{e_t}$	-0.978	-25.974	-0.679	-32.822
	(0.76)	(0.00)	(0.84)	(0.00)
$\boldsymbol{p_t}$	-1.344	-25.229	-1.310	-42.699
	(0.61)	(0.00)	(0.70)	(0.00)
$\boldsymbol{n_t}$	-2.109	-25.416	-0.600	-41.134
	(0.24)	(0.00)	(0.86)	(0.00)

- *Values presented above indicate t-statistic and figures in the parenthesis indicate p-value at 5% level of significance*

Where e_t the representation of foreign exchange market is, p_t is for the commodity market and n_t is for the stock market. During both pre and post-crisis periods, evidence from unit root tests suggest that variables get stationary at their first difference and at levels they are non-stationary, as can be inferred from the Table 2.2. This means that variables follow an I(1) process. As all variables are stationary at first difference, it is appropriate to test whether variables are co-integrated or not. A stochastic trend among any set of non-stationary variables strongly suggests the existence of an equilibrium relationship among them, since an equilibrium relationship implies that the variables cannot independently move. This movement denotes the existence of co-integration.

Table 2.3: Estimation results from Johansen co-integration test

Pre – Crisis

Null hypothesis	*Alternative hypothesis*	**Trace Statistic**	*5% Critical value*
r = 0	r > 0	26.333**	24.276
r≤1	r > 1	05.542	12.321
r≤2	r > 2	01.855	04.130
		Max Eigen Value	
r = 0	r = 1	20.791**	17.797
r = 1	r = 2	03.687	11.225
r = 2	r = 3	01.855	04.130

Post – Crisis

Null hypothesis	*Alternative hypothesis*	**Trace Statistic**	*5% Critical value*
r = 0	r > 0	33.661**	29.797
r≤1	r > 1	07.351	15.494
r≤2	r > 2	00.944	03.841
		Max Eigenvalue	
r = 0	r = 1	26.310**	21.131
r = 1	r = 2	06.406	14.264
r = 2	r = 3	00.944	03.841

***denotes rejection of hypothesis at 5% level of significance.*

Results indicated in Table 2.3 demonstrate the existence of only one co-integrating relationship between the variables during both pre-crisis period and post-crisis period. The lag length for the same is 30 days for the pre-crisis period and 55 days for the post-crisis period based on general to specific methodology.

Typically, one of the variables is used to normalize the co-integrating vector by fixing its coefficient at unity. The study uses commodity price index as the normalizing (dependent) variable and other variables (stock price index and exchange rate) as

independent variables. Results of the same in the pre-crisis and post-crisis scenario can be depicted as follows:

Pre-crisis

$$p_t = 0.891e_t + 0.533n_t + \epsilon_t$$

[6.024] [7.958]

Post-crisis

$$p_t = 3.198e_t - 2.418n_t + \epsilon_t$$

[-2.728] [3.865]

The above equations state that during pre-crisis period, there is a positive relationship between foreign exchange rate and commodity price index and between stock price index and commodity price index. During the post-crisis period, the stock price index has a negative impact on commodity price index; whereas, there is a positive relationship between foreign exchange rate and commodity price index and the values in the parenthesis indicate t-values. In the aftermath of the crisis, not only the nature of the relationship changed but also the magnitude of change was high. A unit change in the exchange rate caused 0.891 unit change in commodity price index in the pre-crisis period and 3.198 units change in the post-crisis period, indicating strong co-integration between the two markets. Whereas, in case of the stock price index, a unit change caused 0.533 unit change in commodity price index in the pre-crisis period compared to 2.418 units change in the post-crisis period signifying strong co-integration after the crisis period. The sign of relationship which was positive in the pre-crisis period turned out to be negative in the post-crisis period.

Considering the time, paths of co-integrated variables, where the trends of co-integrated variables are associated, the dynamic paths of such variables require them to bear some relation to the current deviation from the equilibrium relationship. The linkage between the change in a variable and the deviation from the equilibrium is examined using VECM. This is because, if the system needs to return to its long-run equilibrium, the movements of at least a few of the variables need to respond to the magnitude of the disequilibrium.

Table 2.4: Results from VECM indicating the speed of adjustment parameters

Pre – Crisis

λp	λe	λn
-0.016905**	0.002839**	-0.008762
[-3.53981]	[1.98045]	[-1.13576]

Post – Crisis

λp	λe	λn
-0.001296**	0.000406	-0.002313***
[-2.9866]	[1.8188]	[-4.3395]

*** rejection of hypothesis at 5% level of significance and *** rejection of hypothesis at 1% level of hypothesis. Indicating in the parenthesis are the t-values*

Table 2.4 articulates that during pre-crisis period, any disequilibrium in the commodity price index is corrected with speed of convergence of 1.69 per cent by commodity market and 0.28 per cent by the exchange rate, as the t-statistic is significant for commodity market and foreign exchange market. In the post-crisis period, disequilibrium in the relationship is corrected with the speed of convergence of 0.23 per cent by the stock market and 0.12 per cent by commodity market. Conclusively, the disequilibrium among the markets took about 50 days[7] to come back to equilibrium in

[7] 1.69 per cent + 0.28 per cent = 1.97 per cent , 100/1.97 = 50 days

the pre-crisis period and about 285 days[8] in the post-crisis period. This holds true as the after crisis period has seen a lot of turbulence in the volatility of markets due to changes in exchange rate, capital account deficit, increasing inflation etc., hence it would take a longer period to reach back to an equilibrium state.

The speed of adjustment parameters also describes the long run causality among the variable. In the present study, one can observe that λ_p and λ_e are significant during the pre-crisis period, and λ_p and $\lambda_n$are significant in post-crisis period. Hence, indicating that long-run causality runs from commodity price index to its own future values and to the exchange rate for pre-crisis period and from commodity price index to its own future values and to the stock market in the post-crisis period[9]. Further, in order to check for short-run causality, we restrict the lagged endogenous variables and check if these restrictions are sufficiently binding by means of a χ^2 test. The results of the test presented in Table 2.5 show that in the pre-crisis period only the changes in stock price index cause changes in foreign exchange rate; however, during the post-crisis period it is the stock market that causes changes in both foreign exchange market and commodity market. In other words, in the short-run, there is a unidirectional causality running from stock market price index to exchange rate, both, during the pre-crisis and post-crisis period, however, causality is also found running from stock market to commodity market in the post-crisis period.

[8] 0.23 per cent + 0.12 per cent = 0.35 per cent, 100/ 0.35 = 285 days

[9] The long run co-integrating equation contains p_t as the dependent variable, lagged errors of which represent the error correction term in the VECM framework.

Table 2.5: Results of Granger Causality Test

Pre – Crisis		
Dependent Variable – Δp		
Excluded	*Chi – Sq*	*Inference*
Δe	34.868 (0.250)	$\Delta e \nrightarrow \Delta p$
Δn	34.633 (0.260)	$\Delta n \nrightarrow \Delta p$
Dependent Variable – Δe		
Δp	26.406 (0.654)	$\Delta p \nrightarrow \Delta e$
Δn	50.371 (0.011)	$\Delta n \rightarrow \Delta e$
Dependent Variable – Δn		
Δp	31.278 (0.401)	$\Delta p \nrightarrow \Delta n$
Δe	20.338 (0.907)	$\Delta e \nrightarrow \Delta n$

POST – CRISIS		
Dependent Variable – Δp		
Δe	79.315 (0.017)	$\Delta e \rightarrow \Delta p$
Δn	103.360 (0.000)	$\Delta n \rightarrow \Delta p$
Dependent Variable – Δe		
Δp	87.732 (0.003)	$\Delta p \rightarrow \Delta e$
Δn	88.576 (0.002)	$\Delta n \rightarrow \Delta e$
Dependent Variable – Δn		
Δp	74.316 (0.042)	$\Delta p \rightarrow \Delta n$
Δe	66.043 (0.146)	$\Delta e \nrightarrow \Delta n$

The Granger Causality test under VECM, during the pre-crisis period, concluded that there was no causality among either of the markets except one causal relationship was found running from stock market to foreign exchange market. And in the post-crisis period, the study found that commodity price index changes cause fluctuations in both stock price index and exchange rate, whereas, exchange rate fluctuations caused changes only in the commodity price index, and stock market change cause fluctuations in commodity and exchange rate. The reason for this is, the positive effect of the subprime crisis initially saw added inflows of FIIs into the economy, thereby raising market sentiments as investors felt emerging economies were insulated from the crisis and would act as an alternative engine for growth of the world economy. Later, the crisis did hit the emerging economies, and the impact was felt in terms of reduction in exports, a decline

of industrial growth and employment, depreciation of the rupee, downturn in stock returns and many other indicators. Hence, in the aftermath of the crisis, a causal link was found running from the stock market to the commodity market and exchange rate.

The Quantitative Easing policy by the US created a demand for dollars; this impacted the currency value of many emerging economies and also increased the crude oil prices in international markets. This led to high cost of imports for India, which pushed the rupee to depreciate further and stock markets to fall while commodity prices increased in the economy (positive relationship with foreign exchange market and negative relationship with the stock market).

2.5 CONCLUSION:

The instability in the price movements of the three markets viz. Commodity market, Foreign exchange market and the Stock market has always created an interest in the understanding of the dynamic relationship among these markets. The relationship among the markets is different in the future from that of the past, especially during the times of turmoil. This dynamic linkage among the markets was studied applying Johansen co-integration technique, Vector Error Correction mechanism and Granger Causality test under VECM.

The Johansen co-integration test concluded the existence of a long-run relationship amongst the markets in the pre-crisis and post-crisis period of 2008. Since there existed only one co-integrating equation among the markets, they are not fully co-integrated and therefore the benefits from diversification of portfolio across the markets are reduced (Click and Plummer 2005).

As per the co-integrating equation in the pre-crisis period, stock and forex markets had a positive relationship with the commodity market. And in the post-crisis

period, the nature of the association between exchange rate and commodity market remained the same compared to that with stock market, where the relationship changed from positive to negative and the magnitude also changed. The extent of integration between foreign exchange market and commodity market get highly integrated after the crisis, compared to the extent of integration between stock and commodity market after the crisis period.

The disequilibrium, caused among the markets, was corrected by falling commodity prices, and rising exchange rates since Indian stock markets were assumed to be insulated by financial crisis in US. Hence, stock market showed an increasing price trend, which attracted the investors from commodity markets. Simultaneously, this encouraged some of the Indian companies to increase their imports to meet the rising market demand. Thus, equilibrium was restored by the commodity market and the foreign exchange market, whereas stock market did not undergo any such adjustments. In the post-crisis period, stock market and commodity market made the adjustments to come back to equilibrium position. The stock market prices fell as the Foreign Institutional Investors withdrew their funds from the market and pushed the Indian Rupee to depreciate. But, foreign exchange markets did not correct themselves to restore the equilibrium position. A depreciating Rupee, which generally encourages exports, showed the opposite pattern: exports from the country reduced which reduced the demand for commodities in the market, which pushed the commodities market to fall. But the disequilibrium among the markets takes a longer period to come back to their equilibrium position (50 days in the pre-crisis period versus 285 days in the post-crisis period). Hence, from the Granger causality test it can be seen that in the pre-crisis period, it was the stock market that caused the exchange rate to fluctuate (rising stock prices made the Indian companies to increase their imports to meet the rising demand of the market).

And, in the post-crisis period, the causality among the markets improved and was prominent except for the causal link running from exchange rate to stock market (exchange rate took no efforts to correct the disequilibrium in the market). The authorities, to restore the equilibrium faster among the markets and to encourage investments among investors after the crisis period, can pump in money into the economy by reducing the policy rates. Investors will be in a safer and advantageous position in the long-run rather than in the short-run. If investors do not want to remain invested for long term in the markets, then they need to be cautious about the short-run linkages among the markets and their impact on the real times investment returns. Granger Causality test was applied to document the causal linkages among the financial markets in the short run. In the pre-crisis period, one can find evidence of stock market caused exchange rate. Nonetheless, in the post-crisis period the dynamics of linkages changed and the causal linkage among the markets was found running from the stock market to the commodity market and exchange rate, commodity market to stock market and exchange rate and from exchange rate to commodity market.

Hence concluding that in the aftermath of the crisis, markets have become more interlinked to one another, both in the long-run and short-run. Diversifying investments in commodity market would be advantageous only during pre-crisis period, as the linkage of the exchange rate and stock market to commodity market is weak. On the contrary, the linkage among the markets got stronger in the post-crisis period, as noted, the crisis first affected the stock market, as a result of which there were price changes in the commodity market and exchange rate. Investors need to be cautious before investing in stock market, especially in the immediate aftershock of a crisis.

To conclude, investors can take advantage of this situation by diversifying their portfolio investments to a certain extent in the long run, but at the same time, they have

to be cautious about the short run causal linkages among the markets, which might have an impact on their real investment returns.

2.6 DISCUSSION:

The study is in line with the general view of most of the previous studies such as (Wang, et al. 2010) and (Zhu et al. 2014) where Asian Crisis of 1997 and (Kassim, M. et al. 2009) and (Cheung, W. et al. 2010) during Global Financial Crisis of 2008 came up with the results saying the financial markets globally/ regionally have strong relationship among them through the crisis period and in few cases it even strengthened further in the aftermath of crisis period. On the contrary (Guidi, et al. 2012) analysed the link between Indian and developed Asian stock markets (Japan, Hong Kong and Singapore), indicating an absence of strong linkage among these markets. As discussed earlier, hardly any studies in Indian markets have considered empirically investigating linkage dynamics among the price index of stock market, commodity market and foreign exchange market.They are unlike any of the studies cited under literature review section.Even then, they follow broad conclusion of the studies, of strong linkages among the markets during the crisis period and gets even stronger in the after crisis period; except, a weak linkage was found of foreign exchange market and stock market.

3 THE IMPACT OF MACROECONOMIC ANNOUNCEMENTS ON FINANCIAL MARKETS' VOLATILITY IN INDIA

3.1 INTRODUCTION

In recent years, emerging markets have become an investment hub for many foreign investors with a potentially high rate of return and reduced risk. As much as stock markets have gained importance as an investment option, commodity markets, along with foreign exchange markets, too have gained equal importance in recent years. Earlier, investors rarely considered investing in foreign exchange and commodity markets. But, as the stock markets got volatile, investors started hedging their portfolio risks by diversifying their investments into the commodity market, bond market and foreign exchange markets. As proved by Ingalhalli, V. et al. (2016), commodity markets are highly negatively integrated with the stock market, thereby allowing the investors to take advantage of the situation to earn returns when stock market might not be in good health. Before considering diversifying into various markets, investors should also consider understanding the impact of macroeconomic news announcements on the volatility of each market, especially since macroeconomic news has long been considered to play a key role in the pricing of securities. This is true in the case of developing nations, as the limits imposed through macroeconomic interdependence places burden on their socio-economic and political bases. Financial economics considers linkage dynamics among security returns and macroeconomic risk as its focal point.

However, most of the economy-related information reaches markets randomly over the period: for instance, there are very little prescheduled news announcements of macroeconomic variables that have a profound impact on the market volatility. Though investors will not have any idea about what the content of the news would be, it would be well known to them that there will be some news (Wilson, 2013). If news contained

in the announcements affects the security prices (returns), it is anticipated by the investors that the news would generate higher risk around the investments. This impact of the announcement on stock market prices (returns), Foreign Exchange rates (returns) and Commodity markets (returns) than on the volatility of financial markets, has been well studied in the financial economics literature. One of the main challenges is to understand the information affecting the volatility of asset returns. Information may be macroeconomic announcements, policy announcements, dividend/earning announcements etc. affecting financial asset returns. The study tries to analyse scheduled macroeconomic variables announcement on the volatility of the markets, which would be well known to the investors in advance, but they will not know whether the news would be positive or negative. The markets increase the volatility around the announcement period with anticipation that the news contained will affect the market positively/negatively. Therefore, on the day of an announcement, the volatility reduces as the investors' expectations get realized (Srinivasan, P., 2017).

3.1.1 Foreign Exchange Market reactions to Macro-economic announcements:

Foreign exchange market reactions to the scheduled macroeconomic announcement are subtly problematic. As noted by Riha (2016), in case of any positive domestic news announcements, the market participants believe it would lead to a rise of domestic imports, thereby leading to an increase in demand for foreign currency, thereby letting the domestic currency to depreciate. On the contrary, the positive domestic news may also create a demand for domestic currency and as a result, cause an appreciation of the same. Thus, assuring that any positive news announcement in the domestic market would intensify the volatility of the exchange rate (depreciation/appreciation). This is proved by empirical analysis in the study.

3.1.2 Stock Market Reaction to Macro-economic announcements:

The stock prices replicate investor sentiments towards future cash flows of the companies and various other economic activities that would have an emotional impact on the stock market volatility and, in doing so, affect the stock prices. The fact that the new information released in the market, under the market efficient hypothesis, reflects in the underlying stock prices, thus affecting the volatility. Moreover, the information contained in the macroeconomic indicators holds great interest, as investors are aware of the important scheduled news announcements and consider the news in their potential investment and portfolio risk management. Hence, the announcement of scheduled macroeconomic news like inflation rate, index of industrial production, balance of trade, RBI rate announcement and fiscal deficit increase the volatility of the stock market prior and during the announcement period, and after the announcement, the volatility of the stock market falls, thereby reflecting the inclusion of this news in the stock prices.

3.1.3 Commodity Market Reactions to Macro-economic announcements:

Many institutional portfolio investors added commodities as an asset class to their portfolios. This addition resulted in the growth of the commodity market. One main reason for the rise in commodity derivatives trading is that equity market trading was risky and market participants found a negative relationship between the equity market and commodity market. Due to this, the commodity market was considered as a hedge against equity risk. Commodity market volatility is also affected by macroeconomic variables announcement, having a direct impact on commodity prices. Bohmann, J. M., (2018) reported a statistically significant relationship between announcement and volatility spreads. Their findings indicated that at least some investors are informed about the price impact of the upcoming news announcements, and therefore their behaviour increases the volatility prior to the announcement.

India's GDP growth rate with constant prices with the base year 2004-05 declined to 6.72% in 2008-09 which was 9.32% in 2007-08 due to the global financial crisis following the collapse of Lehman Brothers of US in September 2008. The GDP growth rate enhanced to 8.59% in 2009-10 and 8.91% in 2010-11 owing to an increased capital inflow credited to the Quantitative Easing (QE) undertaken by the US to battle economic slowdown. It further slumped to 6.69% in 2011-12, 4.47% in 2012-13 and 4.74% in 2013-14 due to tax disputes and shaken investor confidence in the Indian economy by foreign institutional investors and domestic investors. Index of Industrial production that had slowed down in 2008-09, picked up in 2009-10; the y-o-y growth rate from April 2008 to April 2009 was 2.52%; this went on improving further with April 2010 seeing a 5.28% growth and April 2011 8.16% growth. Likewise, the trade deficit, which was low in 2008 (negative 126.2 billion USD), fell in 2009 (negative 92.29 billion USD), but further increased and touched its highest point in 2012 (negative 192.87 billion USD). The reason for this was, being in the wake of the global financial crisis, emerging markets were initially considered to be immune against its effects, but the Quantitative Easing policy of US affected the trade balance of many emerging markets (India was one among them).

Increasing demand for the USD led to increased international commodity prices, which affected domestic commodity prices (especially energy and metal commodities). This situation put pressure on the inflation rates (9.70% in 2008, 14.97% in 2009, which was the highest of all and 11.17% in 2012), which was already affected and suffering due to increased aggregate demand of agricultural commodity combined with a low supply of commodities on account of less rainfall. RBI to combat slowing growth rate in 2008-09 reduced repo rate (5.5 in Jan, 2009) to build confidence in investors even though the inflation rate was in double digits. Thus, from 2010 onwards, the RBI slowly increased

the repo rate (September, 2010 – 6.00 and September, 2011 – 8.25)[10](in order to control inflation in the economy. Due to this interlinked situation between growth and inflation, the RBI found it challenging to tackle the problem, and hence it decided to have only one main objective since 2016 that is "Inflation Targeting"[11].

Prior studies in the area of volatility changes were analysed using two main ways (i) through increase/decrease in the prices of financial assets caused by changes in cash flows, and (ii) through increase/decrease in the volume of trading of the financial asset. With a predetermined notion about the impact of a macroeconomic variable announcement on financial market returns, investors react irrationally prior to the announcement, thereby increasing the volatility nearing the announcement date. When the actual information is announced and revealed to the investors, and when they find out that their assumption/prediction has come true, they are satisfied and stop behaving irrationally. Thus, resulting in the disclosure of information contained in the macroeconomic variables and whether it is included in the asset prices. Hence, it can be said that investors, prior to the announcement of scheduled macroeconomic variables data, behave irrationally, thereby increasing the volatility in the market. Once the announcement is made and the investors realize their expectations have been proved correct, they will behave rationally and reduce the volatility in the market. But, if on the day of announcement investors come to know that their expectations were false, they start reacting to the same and increase the volatility in the market even when the announcement is made. From this, it can be said that high volatility in the markets strain fear and concern about the unknown information content in the macroeconomic variables and low volatility in the market indicates stability.

[10] September, 2010 https://rbi.org.in/scripts/BS_PressReleaseDisplay.aspx?prid=23134
September, 2011 https://www.rbi.org.in/Scripts/BS_PressReleaseDisplay.aspx?prid=25076)
[11] https://www.rbi.org.in/scripts/FS_Speeches.aspx?Id=1050&fn=2752

A specific objective of the study is to empirically examine the behaviour of stock price index volatility, commodity price index volatility and foreign exchange rate volatility in response to select scheduled macroeconomic announcements in India. A number of authors in the past decades have attempted to analyse the impact of macroeconomic variables announcement on the stock market, foreign exchange market and commodity market individually in different studies either domestically or cross-border. Golub, S. S. (1983) examined the impact of oil prices on the US Dollar values, whose the main emphasis was on current and capital account balances of US. Results suggested that the US Dollar appreciated in 1973-74 and later depreciated in 1979 due to surging oil prices, the main underlying factor for this sharp shift in the Dollar exchange rate is the dependence of US on OPEC oil imports. Likewise, Bollerslev (1998), using ARCH and GARCH methodology for an annual sample of 5 minute returns in Deutsche Mark–US Dollar foreign exchange rates, provides a detailed characterization of volatility by capturing the intra-day trading activity pattern, macroeconomic announcements effect and persistence of volatility. Outcomes indicate that effects of announcements are short-lived but prevalent at high frequencies, showcasing long memory features. Later, Torben G. Andersen (2003) analysed the impact of macroeconomic news (the difference between expectations and realizations) on the US Dollars spot exchange rates using a weighted least-square procedure, and concluded that conditional mean jumps on account of announcements, thus suggesting the linkage dynamics between exchange rate and the fundamentals. The linkages also pointed out the sign effects of announcements that suggested the market reacts in an asymmetric manner when any news is realised (bad news impacts greater than good news). The above studies analysed the impact of macroeconomic variables on foreign exchange rate within an economy, whereas Jane Kaboro (2018) extended the study across the economies. The study reveals that using a

panel analysis, the explanatory variable (GDP growth rate) had a significant negative impact on exchange volatility in the East African Community countries, which means GDP increase reduces the variability in the exchange rate. Similarly, there are studies that analysed the relationship between macroeconomic variables and commodity markets within an economy. Sephton (1992), using Johansen cointegration technique and Granger Causality test, showed that inflation in agricultural commodity prices was due to currency depreciation. This would allow the central bank of Canada to reduce general price inflation by influencing commodity price inflation in the economy.

Similarly, the commodity prices (gold and silver prices) in the US was significantly impacted by unexpected changes in federal funds rate (Zhang, H. and Thorbecke, W., 2009). Whereas Jena (2016) analysed the domestic commodity price index with international commodity price index in India. Results indicated that Indian agricultural index shared no integration with international commodity price index. On the contrary, all commodity index, energy index and metal index shared a long-run and short-run relationship between domestic and international commodity price index. Next, the stock market volatility analysis is the most studied subject of all. Cutler, D. M. et al. (1988) measured the impact of macroeconomic variables on the stock market returns. Results revealed that the news accounted for one-fifth of the variations in stock market returns fluctuations. It also suggested that a majority of the movements were on non-announcement days.That created a doubt on the view of stock prices movements due to the announcement of news regarding discount rates and future cash flows. Likewise, Kwon, C. S. and Shin, T. S., (1999) analysed the existence of a long-run relationship between macroeconomic variables (production index, exchange rate, trade balance and money supply) and the Korean stock market price returns using Johansen cointegration technique. Simiarly using GARCH(1,1) model, Mark J.Flannery (2002) examined the

impact of 17 macr-economic variables announcement on the equity daily returns and its conditional variance. Among them, six variables turned to have a statistically significant impact on the returns viz consumer price index, producer price index, monetary aggregate, the balance of trade, employment report and housing starts. Smiles, S. and Chaudhari, K. (2004) studied the impact of macro-economic variables on equity returns in Australia using Johansen's cointegration technique. Results reveal the existence of a long run relationship between stock market returns and macroeconomic variables, and vector error correction mechanism suggested that returns are connected to macroeconomic variables changes and deviations from observed long-run relationships.

Likewise, studies using co-integration technique analysed the impact of macroeconomic variables on the stock market prices in various economies found the long-run relationship among the stock returns and macroeconomic variables ((Ratanapakorn, O. and Sharma, S. C., 2007) (Pilinkus, D., 2010)). Omorokunwa, O. G. and Ikponmwosa, N. (2014), using GARCH(1,1) model, revealed that past market information of macro-economic variables affects the stock market price volatility in Nigeria. It also showed that inflation was the major driving force compared to exchange rate and interest rate, which have a weak effect. In SriLanka (Nijam, H. M. et al. 2018), using the OLS regression model, results showed that GDP shares a positive relationship with the stock market, whereas interest rate, exchange rate and inflation showed a negative relationship with the market.

Additionally,a few studies extended the literature in this area by analyzing the impact of macro-economic variables across border stock market returns. Li Li and Hu, Z. F. (1998) analysed the reactions of four stock market indices: (Dow Jones Industrial Index, S&P 500 index, RUSSELL 1000 index and RUSSELL 2000) to macro-economic

variables (money supply, inflation, employment report, trade balance etc.) announcements. It learned that money, supply and inflation had a negative impact on the stock price index, whereas, trade balance innovations had a positive impact on the Dow Jones Industrial index. (Sharma P. W., 2002) using the cointegration technique and Granger causality test investigated linkage dynamics among ASEAN stock markets and select macroeconomic variables (Gross National Product, consumer price index, money supply, interest rate and exchange rate).

Similarly, Macmillan (2009) analysed the long-run relationship between industrial production, consumer price index, long-run interest rates, money supply and stock price index of the US and Japan. Results indicated that US stock price index reacted positively to the announcement of industrial production and negatively to consumer price index. On the other hand, Japanese stock price index reacted positively to the announcement of industrial production and negatively to the money supply. From the above studies, it can be seen that the impact of macroeconomic announcements on domestic stock, commodity and foreign exchange market is not studied together. Also, most of the studies have analysed the impact of announcements (most have considered values) on the mean equation and rarely on the conditional variance of the series. Hence, the purpose of this studies is to try and fill the gap in the literature by examining the impact of macroeconomic variables on the volatility of the stock market, commodity market and foreign exchange market in India.

The rest of the paper is organised as follows: section 2 describes the data considered under the study and methodology followed for analyzing the relationship. Section 3 speaks about the results and analysis, and lastly section 4 contains a brief summary and conclusion.

3.2 DATA AND METHODOLOGY

In order to analyse the impact of scheduled macroeconomic variables announcement on the volatility of markets (stock, commodity and foreign exchange markets), data for macroeconomic variables has been extracted from Bloomberg and that of the stock market from NSE website, commodity market from MCX website and foreign exchange market from RBI website.

Macro-economic variables considered under the study are Inflation, Index of Industrial Production (IIP), Gross Domestic Product (GDP), Fiscal Deficit, RBI Monetary rates announcement and balance of trade. The representative for index price of the stock market is Nifty50, of commodity market is MCX-COMDEX, and of foreign exchange market is Dollar/Rupee. The study uses daily data from 1st September 2008 to 31st August 2016. The following table explains various announcements:

Table 3.1: Description of select macro-economic variables under study

Sr.No.	Macro-economic variables	Frequency of announcements	Acronyms
01	Gross Domestic Product	Quarterly	(GDP)
02	Index of Industrial Production	Monthly	(IIP)
03	Fiscal Deficit	Monthly	(FD)
04	Trade Balance	Monthly	(TB)
05	Inflation	Monthly	(IN)
06	RBI rates	Bi-monthly (Every two months)	(RBI)

The study uses GARCH models to analyse the impact of scheduled macroeconomic variables on the asset returns. Before going in for using GARCH frame work, one must examine the residuals of dependent variables for the presence of conditional heteroskedasticity - The ARCH effect. To do so, the study used ARCH-LM

test proposed by Engle (1982) presented in the following equation and results for the same are disclosed in the following table and residual visualisation in the figure:

$$e_t^2 = \widehat{\delta_0} + \sum_{i=1}^{q} \widehat{\delta_s}\ e_{t-s}^2 + v_t$$

In the above equation squared residuals are regressed on a constant and lagged squared residuals up to order q. The F- statistic is used to check the joint significance of the lagged squared residuals. If the F – statistic is significant then the null hypothesis of No ARCH effects is rejected.

Table 3.2: ARCH-LM test results (ARCH effects)

	Stock Market (Nifty 50)	Commodity Market (MCX COMDEX)	Foreign Exchange Market ($ / ₹)
ARCH-LM test	0.000	0.000	0.000

- *Values shown in the table indicate p-values at 5% level of significance*

Figure 3.1: **Residual graph of stock index price returns**

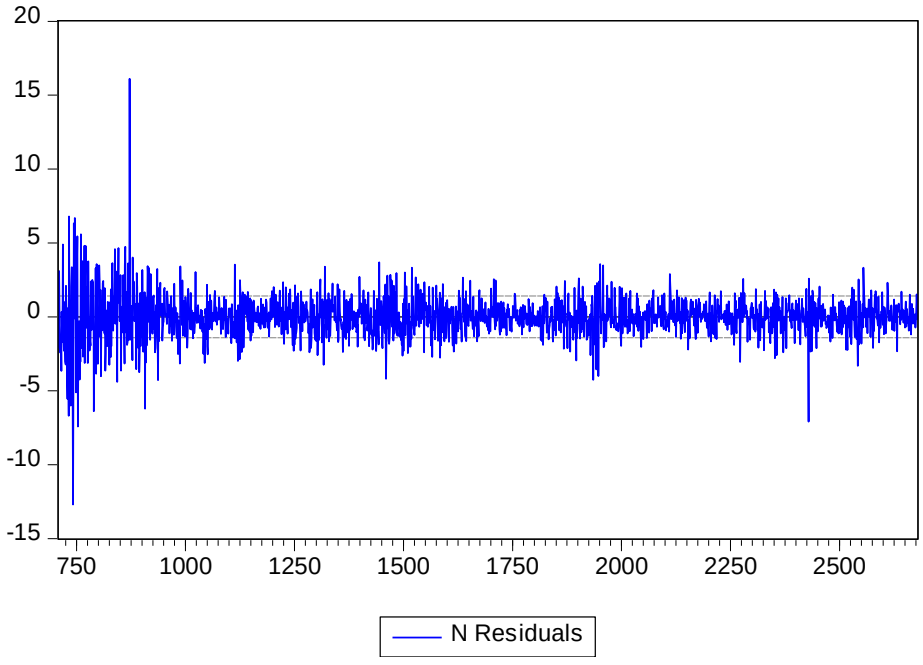


Figure 3.2: Residual graph of commodity index price returns

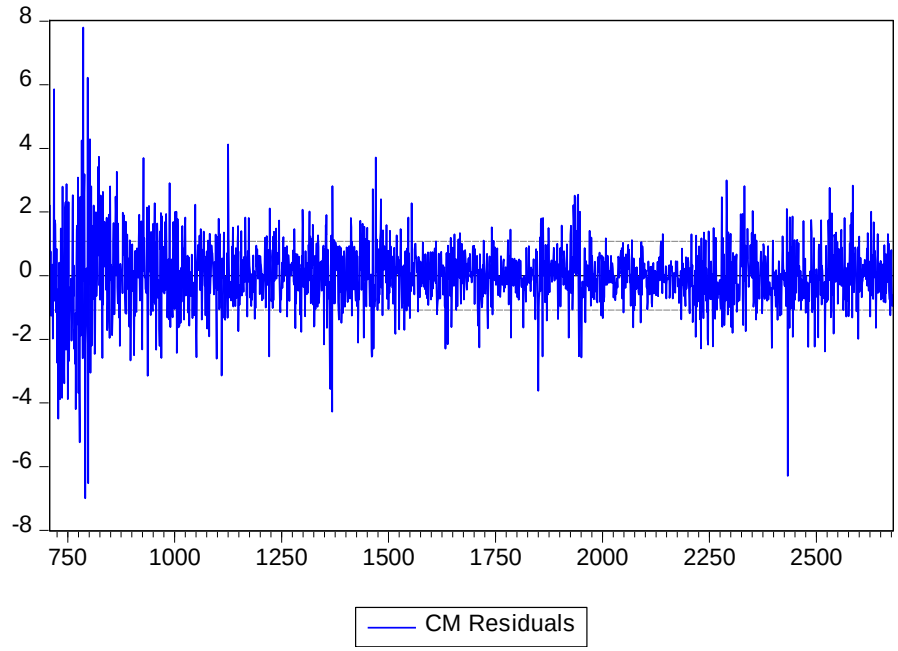
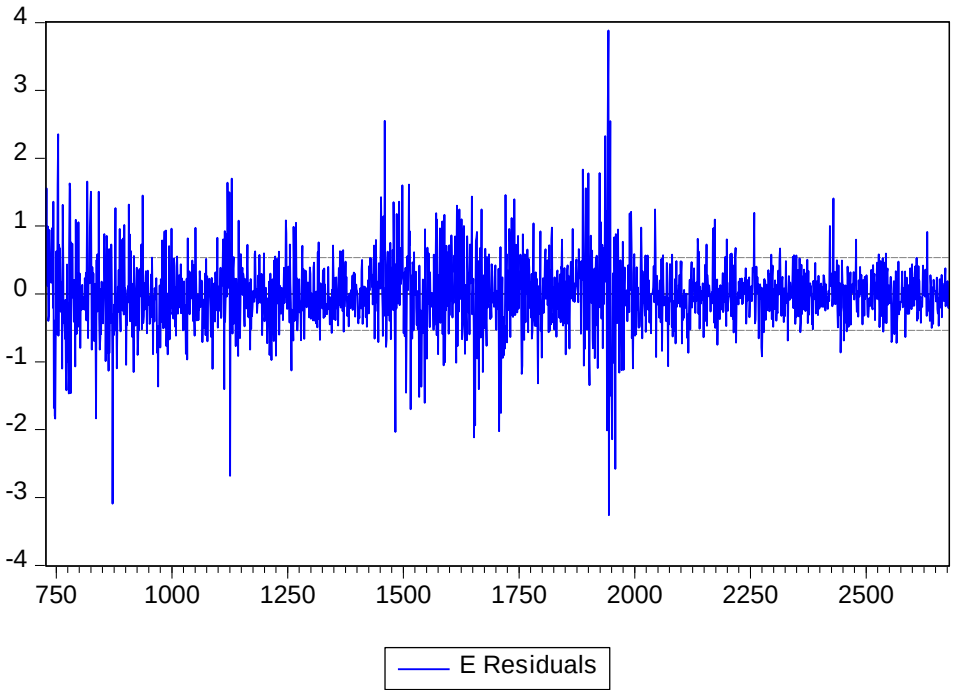


Figure 3.3: Residual graph of foreign exchange rate returns



From the above table and graphs (X axis – dates and Y axis residual figures) results indicate a significant presence of ARCH effects in all the three time series, and hence, GARCH models are suitable for further analysis. It is important to note that after estimating the GARCH models, the ARCH effects should not be present in the residuals

anymore. The presence of ARCH effects in the residuals after estimating the GARCH model implies that it is not specified properly, and one must use a different model to estimate the data (alternatively add more lags or use different error distribution).

GARCH models capture volatility clustering which is an important characteristic of financial time series. GARCH models contain several extensions; two of them are used in the study. GARCH model is a generalization of the previous ARCH model and allows for lags in conditional variance – ARCH term and GARCH term in the variance equation. The model again consists of two equations: Mean equation and Variance equation.

The generalized ARCH model also called as GARCH (p,q), allows for both autoregressive and moving average components in the heteroscedastic variance. The disturbance of the sequence constitutes an ARMA process; this is a key feature of GARCH models. Firstly, the study estimates the ARMA model/auto regression model for "y_t" and simultaneously estimates conditional variance, as they are best estimated simultaneously using maximum likelihood techniques.

Mean Equation

$$y_t = C + \beta_1 y_{t-1} + \varepsilon_t \quad (1)$$

Variance Equation

$$h_t = \alpha_0 + \sum_{i=1}^{q} \gamma_i \, \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \gamma_j \, h_{t-i} \quad (2)$$

where equation 1 is the mean equation and equation 2 is the variance equation. GARCH model allows independent variables to enter into the mean equation and variance equation. "$\sum_{i=1}^{q} \gamma_i \, \varepsilon_{t-i}^2$" indicates ARCH term and $\sum_{j=1}^{p} \gamma_j \, h_{t-i}$ indicates GARCH term in estimating a GARCH(1,1) model. Hence, in order to estimate the impact of macroeconomic variables announcement on the volatility of markets, the study allows these variables to enter into variance equation as a dummy (1 when there is

announcement, and 0 when there is no announcement). Therefore, the following models are put forth for each market:

Model 1 – Stock market

Mean equation

$$n_t = c_1 + \beta_1 n_{t-1} + \varepsilon_t \quad (3)$$

Variance equation

$$h_{11t} = \alpha_{10} + \sum_{i=1}^{q} \alpha_{11} \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \alpha_{12}\, h_{t-j} + \alpha_{13} GDP + \alpha_{14} IIP + \alpha_{15} FD + \alpha_{16} TB + \alpha_{17} IN \;\; \alpha_{18} RBI \quad (4)$$

Model 2 – Commodity Market

Mean equation

$$cm_t = c_2 + \beta_2 cm_{t-1} + \delta_2 \varepsilon_{t-1} + \varepsilon_t \quad (5)$$

Variance equation

$$h_{22t} = \alpha_{20} + \sum_{i=1}^{q} \alpha_{21} \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \alpha_{22}\, h_{t-j} + \alpha_{23} GDP + \alpha_{24} IIP + \alpha_{25} FD + \alpha_{26} TB + \alpha_{27} IN + \alpha_{28} RBI \quad (6)$$

Model 3 – Foreign Exchange Market

Mean equation

$$e_t = c_3 + \beta_3 e_{t-1} + \varepsilon_t \quad (7)$$

Variance equation

$$h_{33t} = \alpha_{30} + \sum_{i=1}^{q} \alpha_{31} \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \alpha_{32}\, h_{t-j} + \alpha_{33} GDP + \alpha_{34} IIP + \alpha_{35} FD + \alpha_{36} TB + \alpha_{37} IN + \alpha_{38} RBI \quad (8)$$

Thus, in all the above three models, the variance equation includes X news about the volatility from the previous period "ε_{t-i}^2", last period's forecast variance "h_{t-j}" and macroeconomic variables announcement as dummies.

The estimated series' errors must be serially uncorrelated in order to obtain a sensible model of the conditional variance. One way to assess the adequacy of the estimated GARCH model is to see how well it fits the data. To do so, maximum likelihood function is used.

In addition to providing a good fit, an estimated GARCH model, if with any extensions (EGARCH / TARCH) should capture all the dynamic aspects of the model of the mean and the model of the variance. The estimated residuals should be serially uncorrelated and should not display any remaining conditional volatility. To test the model of mean, Ljung-box Q-statistic is employed for checking the non-presence of serial correlation; one should not be able to reject the null hypothesis that the various Q-statistics are equal to zero. To test for any remaining GARCH effects, form the Ljung-Box Q-statistics of the squared standard residuals. If there are no remaining GARCH effects, one should not be able to reject the null hypothesis that the sample values of the Q Statistics are equal to zero. Otherwise, there is residual conditional volatility. Then, one can say that the model so obtained is a satisfactory model.

3.3 EMPIRICAL RESULS AND ANALYSIS

A best-fit GARCH model is run to analyse the impact of the announcement variables on the volatility of markets. The following table represents the GARCH model for the stock market, commodity market and foreign exchange market. Wherever the model holds fit in analysing the asymmetry in the response of volatility on the day of the announcement, EGARCH/ Threshold GARCH model is run and analysed to see if there is a difference in the impact of bad/good news on the volatility of the markets. From the

results, it is found that there is no asymmetry in the impact of announcements on the volatility of commodity market, but for stock market volatility, the asymmetry in the response is captured by EGARCH and for foreign exchange market the volatility asymmetric response from macroeconomic variables announcement is captured by Threshold GARCH model. The following table explains the mean and variance equation of stock market returns using EGARCH model.

Table 3.3:EGARCH results for stock market returns

	Variable	**Coefficient**	**P-values**
Mean Equation	Constant	0.0341	0.15
	n(-1)	0.0862	0.00 **
Variance Equation	Constant	-0.1065	0.00**
	ABS(Resid(-1)/ @SQRT(GARCH)(-1)	0.1197	0.00
	Resid(-1)/@SQRT(GARCH(-1)	-0.0706	0.00**
	LOG(GARCH(-1))	0.9900	0.00**
	GDP	-0.2326	0.03**
	IIP	0.0428	0.71
	IN	0.1720	0.11
	FD	0.0168	0.88
	RBI	-0.0603	0.49
	TB	0.2255	0.00**
ARCH-LM TEST	-----	----	0.26

*Note: **denotes significance at the 5% level.*

The above-mentioned mean equation that includes the one-day lag returns of its own market as the exogenous variable, is the best specification as there is no autocorrelation in the residuals of mean equation (refer the Table 6.1 and 6.2 in the

appendix). The conditional variance (volatility) of the stock market shows the presence of leverage effects, as the EGARCH term is negative and significant at 5% level. That means negative shocks increase volatility more than positive shocks i.e. given the value of "h_{t-1}", one unit increase in "ε_{t-1}" will allow for a change in log conditional variance by 0.491 units (0.1197 – 0.0706 = 0.0491). However, if "ε_{t-1}" falls by 1 unit, the log of conditional variance actually declines the volatility by negative 0.1903 units (negative 0.1197 – 0.0706 = negative 0.1903). The results show that good news has a smaller effect on the conditional volatility than bad news. The announcement of GDP decreases the conditional volatility of stock market returns, this holds true as the economy has seen a growing trend GDP except in the year 2009-10. GDP has never fallen to an extreme extent disturbing the sentiments of investors. Hence, it can be said that the information content in GDP announcement reduces the volatility.

On the contrary, the trade balance announcement creates high volatility, this is because since the crisis of 2008 and post-crisis, the current account deficit has increased, affecting the cash flows of the companies directly and indirectly through changes in inflation rates (increase) that leads to changes in discount rate and causing the prices of the stock market to fall, resulting in reduced returns on investment in stock market, leading to increase in its conditional volatility. The insignificance of ARCH coefficient using ARCH-LM test after estimation of the GARCH model, shows that ARCH effect does not exist and the above model best captures stock market volatility.

Table 3.4: GARCH results for commodity market

	Variable	**Coefficient**	**P-values**
Mean Equation	Constant	0.0091	0.64
	AR(1)	0.6483	0.00*
	MA(1)	-0.6176	0.00*
Variance Equation	Constant	0.0011	0.87
	Resid(-1)^2	0.0939	0.00*
	GARCH (-1)	0.8917	0.00*
	GDP	-0.1677	0.04*
	IIP	0.0261	0.72
	IN	0.0307	0.67
	FD	0.1115	0.27
	RBI	0.0652	0.30
	TB	0.1796	0.01*
ARCH-LM TEST	-----	------	0.58

*Note:**denotes significance at the 5% level.*

The mean equation for commodity market returns is explained by its own 1-day past returns behaviour and shock to the market (0.6483 and -0.6176 significant at 5% level respectively). This specification of the mean equation is the best fit as there exists no autocorrelation in the residuals of the mean and variance equations (refer to Table no. 6.3 and 6.4 in the appendix). Ljung – Box Q-statistics is used for checking the model of the mean for the series. The study was not able to reject the null hypothesis that the various Q-Statistics are equal to zero. In a GARCH (1, -1) process, one cannot say that negative news has a higher impact on the conditional volatility than positive news. It is a symmetric model, whether negative news or positive news both will have equal impact,

but increase/decrease in volatility depends only on the magnitude of the shock. The announcement of GDP reduces volatility in the commodity market, as the general expectation is that reasonable increase in GDP rates signifies the economic stability and strength, therefore increasing commodity prices (returns) and lower uncertainty in the market. On the contrary, the announcement of trade balance increases the volatility in the market. This is because of increasing imports and fewer exports triggered by an increase in crude oil prices leading to higher inflation rates and an increase in the cost of production.

Thus, making the investors invest in the commodity market as a hedge against inflation and falling stock prices, thereby leading to a rise in commodity market returns. The coefficients of ARCH and GARCH term (0.0939 and 0.8917 respectively) signify that the volatility shocks are very persistent as the value 0.9856 is close to 1 (0.0939 + 0.8917 = 0.9856). In order to check if the model has captured all the volatility, ARCH-LM test is used and the results fail to reject the null hypothesis of no ARCH effects there by indicating the current model best captures the volatility in the market.

The last model is that for the foreign exchange market. Following Table 3.5 displays mean and variance equations for foreign exchange rate ($ /₹) using TGARCH model.

Table 3.5: Threshold GARCH results for Foreign Exchange Rate Returns

	Variables	**Coefficient**	**P-values**
Mean Equation	Constant	0.0169	0.09
	E(-21)	-0.0745	0.00*
Variance Equation	Constant	-0.0007	0.64
	Resid(-1)^2	0.0837	0.00*
	Resid(-1^ 2*(Resid(-1)< 0)	-0.0487	0.00*
	GARCH(-1)	0.9326	0.00*
	GDP	-0.0111	0.53
	IIP	0.0337	0.03*
	IN	-0.0152	0.30
	FD	0.0374	0.04*
	RBI	0.0047	0.74
	TB	0.0002	0.98
ARCH-LM TEST	-------	-------	0.36

*Note:-**denotes significance at the 5% level.*

The results of mean equation reveal the best specification as proved by Ljung Box Q-statistics (refer table 6.5 and 6.6 in the appendix), which is insignificant from lag1 to lag 30 thus failing to reject the null hypothesis of no autocorrelation in the residuals of the mean equation. The variance equation is estimated using Threshold GARCH model (TGARCH), which is used for analysing of leverage effects in the conditional volatility of the foreign exchange rate returns. The threshold GARCH term is negative (-0.0487), which means positive news has a higher impact on volatility than negative news. Hence, significant values of IIP (0.0337) and Fiscal Deficit (0.0374) prove that the announcement of these variables increases volatility in the exchange rate.

While volatility increase in the foreign exchange market may be due to negative or positive news contained in the announcement, the TGARCH model proposes that positive news raises the volatility more than negative news. IIP rates have always shown positive growth rates except in 2009 & 2013 where it was negative. The positive news attracts more funds & investments from abroad into the economy resulting in higher demand for domestic currency and increasing the volatility of the foreign exchange market. And if news contained in IIP announcement is negative it affects the sentiments of the investors and stakeholders of the companies, which instigates them to withdraw their funds. But this situation is rare, as investors very well know that Indian economy is a developing economy with a strong monetary policy by the central bank, and has a lot of scope for future development. Therefore, investors do not panic when IIP rates fall.

Also, in the case of the fiscal deficit, there has been a rise in the volatility of the foreign exchange market. This is true as positive news contained in fiscal deficit announcement would reduce inflation, thereby indicating a stable economy with efficient government planning and expenditure for its overall development. This attracts funds into the economy directly causing increased volatility in the foreign exchange market. On the contrary, even an increasing fiscal deficit too would cause volatility increase in foreign exchange market by the withdrawal of funds from domestic market by international investors. However, this happened only in 2008-09 due to the financial crisis of 2008 that reduced the aggregate demand in the economy. Hence, it can be concluded that positive news of fiscal deficit has more impact on volatility than negative news of fiscal deficit. The TGARCH model, best captures the volatility in the foreign exchange market, as proved by ARCH-LM test run after estimation of the GARCH model, the coefficient of which is insignificant at 5% level.

3.4 CONCLUSION

The presence of increased volatility in Indian markets from 2008 till 2016, due to the effects of the financial crisis of 2008 and its aftermath effects, motivated the researcher to study the behaviour of scheduled macroeconomic announcements on the conditional volatility of the stock market, commodity market and foreign exchange market.

The representatives of the stock price index are Nifty50, the commodity price index is MCX-COMDEX and the Foreign exchange rate is $/₹. The scheduled macro-economic variables considered under the study are Gross Domestic Product (GDP), Index of Industrial Production (IIP), Inflation (IN), Fiscal Deficit (FD), Trade Balance (TB) and RBI rates announcement (RBI). Previous studies have mostly considered analysing the impact of macroeconomic variables announcement on the returns of individual markets.

But, this study distinguishes itself by analysing the announcements impact on the conditional variance of the three markets in the Indian context. It uses appropriate GARCH (1,1) models and its extensions in modelling the volatility of the markets. The best model for modelling the stock market returns volatility is the EGARCH model, which is used for capturing leveraged whereas for commodity market returns volatility GARCH (1,1) model and for foreign exchange rate returns volatility TGARCH model is used for capturing leverage effects. The empirical results reveal that GDP announcements reduce the volatility in both commodity market and the stock market, but for foreign exchange market, it is insignificant. Moreover, the announcement of trade

balance increases the volatility of the stock market and commodity market, but, there has been negligible impact of the same on the foreign exchange market. In case of the foreign exchange market, announcement of Index of Industrial Production and Fiscal Deficit created a rise in the volatility. The results hold true as the performances of macroeconomic variables indicate economic stability, growth & a strong monetary policy that did not allow the economy to stumble to a great extent and create unrest. Thus, it attracted investments not only from domestic investors but also from foreign investors.

Hence, it is suggested that investors keep a close watch on these significant announcements so that they can take advantage of price changes (returns) in each market which will have an effect on their portfolio returns. The study can be further extended by analysing the impact of announcements on the conditional volatility of each market and whether it spillovers to other markets as well.

4 VOLATILITY SPILLOVER AMONG THE STOCK, COMMODITY AND FOREIGN EXCHANGE MARKETS IN INDIA.

4.1 INTRODUCTION

In the view of volatility spillover across the financial markets (stock and foreign exchange markets) and commodity market in India, understanding the interactions among these markets will allow investors in making informed hedging and trading strategies. As the series do not have constant mean and variance, any kind of shock in the market will showcase high degree of volatility persistence and this volatility will vary over time, it is, therefore, crucial to have awareness of volatility dynamics among these markets, prior to venturing into trading or making any policy decisions. In other words, prior to the pricing of securities, asset allocation decision-making or deciding on an appropriate hedging strategy, examining the source of volatility and its behaviour is important. Among the three markets (stock, foreign exchange and commodity markets), the commodity market is considered for hedging of portfolio risk through diversification either in physical commodities or derivatives.

The opening up of the economy has played a crucial role in the determination of domestic commodity prices, as they are frequently subject to changes in international commodity prices. Jena (2016) suggested that price changes in domestic commodity index are due to changes in the international commodity index. The commodity prices amplified since 2002 due to significant fluctuations in demand and supply imbalances, increase in biofuels demand, crude oil prices rose and hype in speculative transactions of commodity derivatives in the global market.

The Indian Rupee against US Dollar started depreciating since October, 2008 on account of US financial crisis of 2008; May, 2009 saw a slight improvement in the Rupee value and continued till 2012-13. May, 2013 again witnessed depreciation of the Rupee

as demand for the Dollar started increasing due to improving unemployment rate in US economy and financial aid provided by US government. Combined with an increased demand for dollars and large capital outflows by oil firm importers, corporate companies and banks pushed the Rupee to depreciate. This further depreciation of the Rupee continued, in spite of efforts by RBI to stabilize the Rupee value through the selling of US dollars from its foreign reserves, increase in customs duty on imports of gold and striking various restrictions on outflows of foreign exchange. The Rupee value depreciated to a record low level of ₹68.83 to a Dollar on August 28, 2013; the main reason besides outflow of capital flows was a widening of the Capital Account Deficit. One of the main reasons for capital account deficit during 2013-14 was the import of gold for investment and consumption purpose by the public. Investors chose investment in gold as a hedge against rising inflation during 2012-13 and 2013-14. The other reason was the import of crude oil that increased capital account deficit to 6.7% of GDP, which way above the comfort level specified by RBI.

Furthermore, 2016 saw a further Rupee depreciation that began in 2013-14, that kept dragging downwards due to a decrease in exports since December 2014. Another reason was capital outflows by foreign institutional investors, who sold $2.45 billion in equities of which $844.5 million was offloaded in the first two months of 2016 itself. These series of events affected interlinkages among the three markets creating a vicious circle that would always exist on the occurrence of events that would affect one market and spillover to other markets as well.

Transmission of information across markets conveys interdependencies amongst them, due to which, analysing these interdependencies and various factors leading to this interdependence has gained importance among the researchers. The prime focus of early

researches was on first moment (mean) spillovers of financial markets, whereas in the recent years the much-researched topic is the second moment (variance) analysis (Kedarnath Mukherjee, 2010). The variance of one market gets affected by its own past variance and/or by the variance of other markets, which suggests co-movements among them. Hence, inter-linkages in the second moments of financial markets are a significant factor influencing relationships among financial markets.

Previous studies revealed the relationship dynamics among stock market, foreign exchange market, gold prices and oil prices in various combinations both internationally and domestically. The increasing interdependences among the stock markets reveal the transmission of information among the markets. These transmissions are nothing but spillovers among the markets.

Various studies using GARCH methods have also tried analyzing price and volatility spillovers (first and second-moment interactions respectively) among various stock markets. Akgiray (1989) used ARCH and GARCH methodology to model the conditional heteroscedasticity present in the time series of stock market returns, revealing that GARCH model forecasts are superior in comparison to ARCH model forecasts. Also, Karolyi (1995) using bi-variate GARCH model and Impulse Response function examined short-run price movement dynamics between stocks traded on Toronto Stock Exchange and New York Stock Exchange. It says that volatilities in cross-market patterns have changed over time and magnitude of shocks had a diminishing impact on Toronto Stock Exchange that originated from New York Stock Exchange. Similarly, Kedarnath Mukherjee (2010) reveals the transmission of information among the Indian and twelve other Asian markets using GARCH(1,1) methodology and concludes that

information gets transmitted mostly without any delay, still some information that remains gets transmitted soon as the market opens next day.

Likewise, there are studies that analysed mean and volatility spillover effects across equity markets in various countries and across countries using multivariate GARCH models ((Anne, T. and Labidi, C. 2006), (Bhar, R. and Nikolava, B., 2007), (Teulon, F., et al. 2014)). Furthermore, Baele, L. (2005), using the Regime Switching model, analysed volatility spillover effects in European equity markets, wherein it tries to quantify the magnitude and time-varying nature of spillovers. In the same way, (Patnaik, A., 2013) conducted volatility spillover study across select foreign exchange rates in India using the DCC-GARCH model. The study showed the prevalence of high volatility clustering and spillover effects among the exchange rates, as a result only short-term action policies can be framed.

Moreover, using both co-integration and VECM or VAR methodology, studies have proved the nonexistence of relationship between exchange rate and stock market (Gulati, D. and Kakhani, M. 2012), (Sujit, K. S. and Kumar, B. R., 2011), (Mu-Lan Wang, M-L. et al. 2010). Whereas, Morales, L. (2008), applying E-GARCH methodology, analysed volatility spillover between stock returns and exchange rates of six Latin American countries and one European economy. It revealed that the volatility of exchange rates are affected by volatility from stock returns.

From the above literature review, it can be inferred that MV-GARCH models are mostly used to study the volatility spillover effects among multi-assets within/across countries. The motivation for studying the case of volatility spillover effects between stock market, exchange rate and commodity market in India came from the fact that previous studies considered examining relationship of gold price and oil price with

exchange rate and stock market, by ignoring the fact that gold price and oil price together contribute approximately 50% of commodity index weight, thus allowing scope to examine the relationship between stock market, foreign exchange market and commodity market. Studies in the past have ignored the commodity index in examining the financial relationship dynamics within the country. Hence, this study considers including commodity index in examining volatility linkages among stock market, exchange rate and commodity market instead of individual commodities.

4.2 DATA AND METHODOLOGY

The study uses daily closing prices of Nifty50 as representative of stock exchange index, MCX-COMDEX as representative of Commodity index and Rs./$ for exchange rate representation. Data is collected from 1st September 2008 till 31st August 2016.

4.2.1 METHODOLOGY

The prerequisite for using GARCH models requires testing for the existence of ARCH effects in each of the mean equation; this would be tested for using ARCH-LM test.

Mean equation for each return series:

$$R_{it} = \mu_i + \alpha R_{it-1} + \varepsilon_{it} \quad (1)$$

In equation 1, R_{it} denotes returns of the series at the time$'t'$, μ_i indicates long-term drift coefficient and ε_{it} is the error at the time$'t'$. On estimating equation (1), the residuals of the equation $'\varepsilon_{it}'$ were tested for the existence of ARCH effects using ARCH-LM test (Engle, 1982). The study found the presence of ARCH effects in the markets under consideration; the results of the same are produced in Table no.4.1.

Table 4.1: Results of ARCH-LM test

	p-value
Stock Market	0.00*
Commodity Market	0.00*
Foreign Exchange Market	0.00*

**p-value significant at 5% level of significance*

Evidence of the presence of ARCH effects leads to usage of appropriate Tri-variate GARCH model, allowing the study to capture the transmissions of volatility among different series as well as the persistence of volatility within each series. The study considers using BEKK-GARCH model (named after Baba, Engle, Kraft and Kroner, 1990) as a representation of the Tri-variate GARCH(1,1) model is given as:

$$H_t = C'C + A'\varepsilon_t\varepsilon'_{t-1}A + B'H_{t-1}B \qquad (2)$$

where H_t represents a conditional variance-covariance matrix; $C$is a 3X3 lower triangular matrix with six parameters; B is a square matrix that depicts the extent to which the present variances are related to past conditional variances; and A is a 3X3 square matrix with nine parameters that capture the lagged effects of shocks and events on the volatility of markets under consideration. The total number of parameters estimated for the variance equations, in this case, would be twenty-four.

$$\begin{bmatrix} h_{11t} & h_{12t} & h_{13t} \\ h_{12t} & h_{22t} & h_{23t} \\ h_{13t} & h_{23t} & h_{33t} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{12} & c_{22} & c_{23} \\ c_{13} & c_{23} & c_{33} \end{bmatrix}\begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{12} & c_{22} & c_{23} \\ c_{13} & c_{23} & c_{33} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{21} & \alpha_{31} \\ \alpha_{12} & \alpha_{22} & \alpha_{32} \\ \alpha_{13} & \alpha_{23} & \alpha_{33} \end{bmatrix}\begin{bmatrix} \varepsilon_{1t-1} \\ \varepsilon_{2t-1} \\ \varepsilon_{3t-1} \end{bmatrix}$$

$$\begin{bmatrix} \varepsilon_{1t-1} & \varepsilon_{2t-1} & \varepsilon_{3t-1} \end{bmatrix}\begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix}$$

$$+ \begin{bmatrix} \beta_{11} & \beta_{21} & \beta_{31} \\ \beta_{12} & \beta_{22} & \beta_{32} \\ \beta_{13} & \beta_{23} & \beta_{33} \end{bmatrix}\begin{bmatrix} h_{11t-1} & h_{12t-1} & h_{13t-1} \\ h_{12t-1} & h_{22t-1} & h_{23t-1} \\ h_{13t-1} & h_{23t-1} & h_{33t-1} \end{bmatrix}\begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix}$$

By expanding the variance system H_t, the conditional variance for each equation is as follows:

$$h_{11t} = (c_{11}^2 + c_{12}^2 + c_{13}^2) + [(\alpha_{11}\varepsilon_{1t-1})^2 + (\alpha_{21}\varepsilon_{2t-1})^2 + (\alpha_{31}\varepsilon_{3t-1})^2 + 2(\alpha_{11}\alpha_{21}\varepsilon_{1t-1}\varepsilon_{2t-1}) + 2(\alpha_{11}\alpha_{31}\varepsilon_{1t-1}\varepsilon_{3t-1}) + 2(\alpha_{21}\alpha_{31}\varepsilon_{2t-1}\varepsilon_{3t-1})] + [\beta_{11}^2 h_{11t-1} + \beta_{21}^2 h_{22t-1} + \beta_{31}^2 h_{33t-1} + 2(\beta_{11}\beta_{21}h_{12t-1}) + 2(\beta_{11}\beta_{31}h_{13t-1}) + 2(\beta_{21}\beta_{31}h_{23t-1})] \quad (3)$$

$$h_{22t} = (c_{12}^2 + c_{22}^2 + c_{23}^2) + [(\alpha_{12}\varepsilon_{1t-1})^2 + (\alpha_{22}\varepsilon_{2t-1})^2 + (\alpha_{32}\varepsilon_{3t-1})^2 + 2(\alpha_{12}\alpha_{22}\varepsilon_{1t-1}\varepsilon_{2t-1}) + 2(\alpha_{12}\alpha_{32}\varepsilon_{1t-1}\varepsilon_{3t-1}) + 2(\alpha_{22}\alpha_{32}\varepsilon_{2t-1}\varepsilon_{3t-1})] + [\beta_{12}^2 h_{11t-1} + \beta_{22}^2 h_{22t-1} + \beta_{32}^2 h_{33t-1} + 2(\beta_{12}\beta_{22}h_{12t-1}) + 2(\beta_{12}\beta_{32}h_{13t-1}) + 2(\beta_{22}\beta_{32}h_{23t-1})] \quad (4)$$

$$h_{33t} = (c_{13}^2 + c_{23}^2 + c_{33}^2) + [(\alpha_{13}\varepsilon_{1t-1})^2 + (\alpha_{23}\varepsilon_{2t-1})^2 + (\alpha_{33}\varepsilon_{3t-1})^2 + 2(\alpha_{13}\alpha_{23}\varepsilon_{1t-1}\varepsilon_{2t-1}) + 2(\alpha_{13}\alpha_{33}\varepsilon_{1t-1}\varepsilon_{3t-1}) + 2(\alpha_{23}\alpha_{33}\varepsilon_{2t-1}\varepsilon_{3t-1})] + [\beta_{13}^2 h_{11t-1} + \beta_{23}^2 h_{22t-1} + \beta_{33}^2 h_{33t-1} + 2(\beta_{13}\beta_{23}h_{12t-1}) + 2(\beta_{13}\beta_{33}h_{13t-1}) + 2(\beta_{23}\beta_{33}h_{23t-1})] \quad (5)$$

The above equations (3, 4 and 5) measure the volatility transmissions and effects across the variables over a period of time. Likewise, the equation coefficients of (3), (4) and (5) are non-linear functions of BEKK-GARCH equation elements (2). Hence, the standard errors for these coefficients are estimated using the delta method, that is derived from first-order Taylor expansion around its mean following (Patton, 2000).

4.3 EMPIRICAL RESULS AND ANALYSIS

The conditional variance of stock market index returns at time 't' is denoted by h_{11t} (stock returns equation); the conditional variance of exchange rate returns at time 't' is denoted by h_{22t} (exchange rate equation); and the conditional variance of commodity index returns at time 't' by h_{33t} (commodity equation). Likewise, h_{12t-1},

h_{13t-1} and h_{23t-1} denote conditional co-variances between stock index returns and exchange rate returns, stock index returns and commodity index returns, and exchange rate returns and commodity index returns respectively, affecting the conditional variances of said markets at time 't'.

The unexpected shocks/news arising from the stock market, foreign exchange market and commodity market are subscripted by 1, 2 and 3 respectively, and captured by ε_{1t-1}^2, $\varepsilon_{2t-1}^2$and ε_{3t-1}^2 (squared error terms). Similarly, cross products of error terms, ε_{12t-1}, ε_{13t-1} and ε_{23t-1} represent indirect shock/news impact.

Table 4.2
Results of volatility spillover across the stock market, foreign exchange market and commodity market using BEKK GARCH model.

Variables	h_{11t}		h_{22t}		h_{33t}	
	coefficients	p-value	coefficients	p-value	coefficients	p-value
h_{11t-1}	0.944	0.00**	0.000	0.65	0.002	0.00*
h_{22t-1}	0.012	0.16	0.000	0.93	0.017	0.18
h_{33t-1}	0.000	0.01**	0.000	0.80	0.990	0.00**
h_{12t-1}.	-0.210	0.00**	0.000	0.88	-0.011	0.00**
h_{13t-1}	-0.017	0.00**	0.000	0.64	0.084	0.00**
h_{23t-1}	0.002	0.02**	0.000	0.86	-0.256	0.01**
ε_{1t-1}^2	0.030	0.00**	0.000	0.63	0.026	0.00**
ε_{2t-1}^2	17.872	0.00**	54.450	0.00**	0.599	0.00**
ε_{3t-1}^2	0.000	0.50	0.000	0.82	0.016	0.00**
ε_{12t-1}	-1.453	0.00**	0.115	0.34	0.250	0.00**
ε_{13t-1}	-0.006	0.17	0.000	0.66	-0.041	0.00**
ε_{23t-1}	0.135	0.18	-0.042	0.64	-0.196	0.00**
C	0.193	0.00**	0.183	0.00**	0.000	0.39

*** indicate significance at 5% level of significance*

The estimated results of BEKK GARCH model for each variance equation ($h_{11t}, h_{22t}\ and\ h_{33t}$) are presented in Table 4.2. It can be noted that the volatility spillovers among the said markets are extensive and reciprocal except for the foreign exchange market. In addition to their own past news/innovations, the conditional variance of each market is affected by news generated from other markets.

The conditional variance of stock market index returns (h_{11t}) at time 't' directly incorporates not only the volatility and news emerging from its own market (check the significant coefficients of h_{11t-1} and ε_{1t-1}^2) but also the volatility from commodity market (evidence from significance level of h_{33t-1}). Moreover, commodity market volatilities indirectly affect the stock market and foreign exchange market (significance is indicated by $h_{13t-1}\ and\ h_{23t-1}$), and later again affecting the conditional variance of the stock market. In addition, news emerging from foreign exchange market also affects, directly and indirectly, the variance of the stock market, whereas volatilities indirectly affect the said market (results indicated by significant coefficients of ε_{2t-1}^2, $\varepsilon_{12t-1}$and h_{12t-1} respectively).

Conditional variance of the foreign exchange market (h_{22t}) is affected only by news emerging from its own market (check the significant coefficient of ε_{2t-1}^2).

While, conditional variance of the commodity market (h_{33t}) is directly affected by news emerging from its own market, stock market and foreign exchange market (evidence from significant coefficients of ε_{3t-1}^2, $\varepsilon_{1t-1}^2\ and\ \varepsilon_{2t-1}^2$) as well as by volatilities from stock market and its own market (observe the significance level of $h_{22t-1}\ and\ h_{33t-1}$). Furthermore, the news and volatilities emerging from the stock market and foreign exchange market (check the significant coefficients of$\varepsilon_{13t-1}, \varepsilon_{23t-1}, h_{13t-1}, and\ h_{23t-1}$) indirectly affect the conditional variance of the commodity market. Likewise, news and volatility from foreign exchange market indirectly affect the stock market variance (coefficient significance of$\varepsilon_{12t-1}\ and\ h_{12t-1}$), which spills over to the commodity market thereby affecting its conditional variance.

Various situations and factors affect the volatility spillovers across markets during the said period under study. One such is the 2008 US crisis that resulted in the drying up of the US Dollar liquidity, which created an increased demand for dollars in the global markets. This news directly affected the stock market returns, as the foreign institutional investors withdrew their investment from the country in the view of financing their domestic expenses, resulting in the depreciation of the Indian Rupee. This further brought about uncertainty among the domestic investors, who further sold their investments as well leading to falling in stock market prices and thereby directly affecting stock returns. Depreciation in the Indian Rupee affected firms' real income by affecting their cost of imports and exports. This reduction in firms' real income resulted in lower rate of return on investments that further caused the stock prices to fall as the expectations of investors fell leading to a fall in stock prices. Thus, the news of depreciation indirectly affected the Indian stock market returns.

Moreover, due to the depreciation of the Indian Rupee, import commodity prices increased. As the commodity prices rose, companies had to pay extra in manufacturing the products. This increase in cost was either passed on to the consumers – increasing the price of products; or by including it in the margins – price remaining the same. Both these cases would lead to lowering the earnings of the company through reduced sales or a decrease in profit margins respectively. This exhibits that foreign exchange market news directly affects commodity market volatilities, and commodity market fluctuations directly affect stock market volatilities.

On the other hand, stock market volatility is indirectly affected through rising inflation created by increasing commodity prices for the reason that inflation shares a positive relationship with commodity prices and negative relationship with stock prices,

thereby proving a negative indirect relationship between commodity market and the stock market. The commodity market volatility affects foreign exchange market volatility and in so doing affecting the conditional variance of stock market. This is explained by an increase in price of export commodities that leads to creation of demand for the Indian Rupee (appreciates) in that way making imports cheaper for companies and swelling the earnings of the companies, making their stock prices to upsurge producing higher returns for investors.

The results hold true in the case of conditional variance of the commodity market, as any news from global oil companies on the pricing of oil affects the stock market volatility by impacting oil producing companies profit margins and non-oil producing companies cost (energy consumption cost): a spike in oil prices will generate lower income and further lower stock returns. The increase in commodity prices due to increase in oil prices (energy consumption cost and transportation cost) leads to increase in inflation; investors diversify their investments into commodities to hedge against inflation (investment in gold is considered as a hedge against inflation and currency depreciation, as it provides high liquidity for investors). This explains the direct and indirect impact of volatilities and news/innovations from the stock market and commodity on conditional variance of the commodity market. The increase in global oil prices exerts pressure on the Indian Rupee causing it to depreciate further, thereby affecting the dynamics of domestic oil prices and decisions taken by oil companies in India, and thereby proving the impact of foreign exchange market on stock market price returns and thereby on commodity market price returns.

High global oil prices exert pressure on inflation globally which further force the world gold prices to go up. These commodities create a huge demand for US dollars,

which affects the other currencies denominated in dollars. Thus, globally traded commodities push the exchange rate to either inflate or depreciate and affect the domestically traded commodities prices through changes in demand and supply. This explains the indirect impact of news/innovations in the foreign exchange market on commodity market price returns.

However, conditional variance of foreign exchange market in India is significantly affected by the news/innovations affecting the FOREX markets directly, resulting in an increase in demand of the US Dollar, there by depreciating the Indian Rupee. Whereas, it is not affected as considerably by any other markets volatility or news/ innovations as the other coefficients are statistically insignificant.

4.4 CONCLUSION

Transmission of information across financial markets conveys interdependence through volatility spillovers among the markets. The motivation for studying the case of volatility spillover effects between stock market, exchange rate and commodity market in India came from the fact that previous studies considered examining relationship of gold price and oil price with exchange rate and stock market while ignoring the fact that gold price and oil price together contribute approximately 40% of commodity index weight, thereby allowing a scope to examine the relationship between stock market, foreign exchange market and commodity market. The data considered is from 1st September 2008 till 31st August 2016 using BEKK GARCH model to analyse the volatility spillovers across the said markets. The precondition for running BEKK-GARCH model is checking for the presence of ARCH effects, this is confirmed using ARCH-LM test. BEKK-GARCH model results indicated that volatility spillovers among the said markets are extensive and reciprocal except in the foreign exchange market.

Conditional variance of stock market price returns are affected by volatilities and news/innovations arising from its own market and as well as from commodity and foreign exchange markets, except from the statistically insignificant coefficients of direct and indirect news/innovations arising from commodity market, and direct volatilities and indirect news/innovations arising from foreign exchange market. Likewise, the commodity market's conditional variance too is affected by direct and indirect volatilities and news/innovations from its own market and stock market.

Similarly, news/innovations from foreign exchange market, directly and indirectly, also affect the conditional variance of the commodity market; volatilities too affect indirectly, with the exception that direct volatility from foreign exchange market is insignificant in causing changes in conditional variance of commodity market. On the other hand, the conditional variance of the foreign exchange market is only affected by the news generated from its own market and all other coefficients are statistically insignificant. The spillovers among the markets are largely influenced by US 2008 crisis that impacted the capital flows of the economy, fluctuating globally traded commodity prices (for instance, largely by oil and gold prices) and exchange rate fluctuations.

The study makes a suggestion to investors to have managed portfolios; this can be done by adding commodity market index to their traditional portfolios of stocks and bonds, which will lower reduce risk and improve overall diversification. Commodity market returns are negatively correlated with stock market returns, and are positively correlated with inflation, and adding commodities to traditional portfolios would improve its efficiency. With changing environmental conditions, investors may, with the help of professional managers, need to keep rebalancing their portfolios to achieve meaningful diversification.

5 SUMMARY, FINDINGS AND CONCLUSION

5.1 SUMMARY

The integration among stock market, foreign exchange market and commodity market has increased over the years due to factors such as macroeconomic variables, hedging activities in interlinked markets undertaken by investors, financial crises, etc. Besides the shocks/events that affect that a financial market, conditional variance will have an impact on the other inter-linked markets, thereby influencing the real rate of return on investments of investors diversifying their portfolio internationally. Thus, the study aims at examining and understanding the dynamic linkages among the financial markets in India by analyzing volatility linkages among the markets. The huge capital flows among the economies has made stock and foreign exchange market highly integrated. They share a time-varying relationship, which may be negative at times and positive at the other. Similarly, the commodity market and the stock market too share a relationship due to hedging advantage displayed by commodity market during times of uncertainty in the stock market. Conversely, the commodity market and the foreign exchange market share a positive relationship. This is mostly due to changes in the globally traded commodities.

Having this broad conceptual understanding in the backdrop, the study has tried to analyze the extent of integration among the three markets and their short-run causal relationship. Besides, the study has also tried to examine the changes in the volatility of each market on announcement of select macroeconomic variables. Along with, the study has attempted to examine if the conditional volatilities of the markets are influenced by the spillover (volatility and information) from other interlinked markets.

Previous literature on linkage dynamics among the markets was also studied keeping commodity market as an investment avenue aside. They considered individual

commodity prices and their impact on returns of financial markets either domestically/ internationally. In the initial years, the commodity market was only considered for physical trading of commodities and hedging against the price risk. But in the recent past, it has been recognized as an investment option by investors to hedge against the risk in other financial markets. The study has contributed to the limited literature that exists on linkages among the stock market price index, commodity price index and foreign exchange market. The study is divided into three objectives:

1. To examine the integration among the markets during pre and post-crisis period of 2008.
2. To empirically examine the conditional variance behavior of the markets in response to select scheduled macroeconomic announcements in India.
3. To investigate the volatility spillovers across markets.

To analyze these the study employed Johansen co-integration technique, Vector Error Correction Mechanism, Granger Causality test and family of appropriate GARCH models.

5.2 FINDINGS

- The applied Chow test confirmed that 1st of September, 2008 was the breakpoint for dividing the period into pre-crisis and post-crisis of 2008.
- It also found the presence of one co-integrating relationship among stock, commodity and foreign exchange markets in India.
- The co-integrating equations for pre-crisis period indicated weak positive relationship between commodity market and exchange rate market, and commodity market and stock market.

- In the post crisis period, markets showed a strong positive relationship between commodity market and foreign exchange market and, strong negative relationship between commodity market and stock market.
- In the pre-crisis period, any disequilibrium among the markets was adjusted by commodity market by falling, and exchange rate by rising.
- In the post crisis period, the disequilibrium is restored by commodity market by falling, and stock market by falling; foreign exchange market does no adjustments.
- The Granger causality test under VECM framework in the pre-crisis period indicated no causal relationship among the market except that a causal link was found running from stock market to foreign exchange market.
- In the post-crisis period, the causal relationship among the markets showed significant link, except for an absence of a causal link running from foreign exchange market to stock market.
- The conditional volatility of stock market is influenced by the announcement of GDP and trade balance, wherein the announcement of GDP reduces the volatility, and trade balance increases volatility in the stock market. The results also reveal that negative news create more volatility compared to positive news in the stock market.
- The conditional volatility of commodity market is affected by the announcement of GDP and trade balance. GDP reduces the volatility on announcement, whereas trade balance increases the volatility on announcement in the market.
- In the case of foreign exchange market, its conditional volatility is impacted by the announcement of Index of Industrial Production and Fiscal Deficit. Both these variables create volatility in the foreign exchange market on announcement.

- The conditional variance of stock market is influenced directly and indirectly by the volatilities and news emerging from its own market and from commodity market. Whereas, in case of foreign exchange market, the news and volatilities affect the stock market indirectly.
- Except for volatilities arising in the foreign exchange market that have a direct impact on the commodity market volatilities, the conditional variance of commodity market is sensitive to the volatilities and news arising from its own market and stock market directly and indirectly.
- The foreign exchange market volatility is highly influenced by news arising from its own market, whereas, the volatilities and news from other markets barely affects the conditional variance of foreign exchange market.

5.3 CONCLUSION

The markets in the pre-crisis period showcased low co-integration which got stronger after the crisis period. The commodity market acted as a safe haven for investors during post crisis period, as it shared a negative relationship with the stock market. The disequilibrium caused among the markets was corrected by falling commodity prices and rising exchange rates. This is because Indian stock markets were assumed to be insulated by financial crisis in US. Hence, stock markets showed an increasing price trend, which attracted investors from commodity markets. Simultaneously, this encouraged some Indian companies to increase their imports to meet the rising market demand. Thus, the equilibrium was restored by the commodity market and the foreign exchange market, wherein stock market did not correct itself.

In the post-crisis period, stock market and commodity market made adjustments to come back to equilibrium position. The stock market prices fell as the Foreign

Institutional Investors withdrew their funds from the market, pushing the exchange rate to depreciate. However, the foreign exchange market didn't correct to restore the equilibrium position. A depreciating Rupee, a phenomenon, which generally encourages exports, showed a converse trend, i.e. the exports of the country reduced, which reduced the demand for commodities in the market, which pushed the commodities market to fall.

But, the disequilibrium among the markets takes a longer period to come back to their equilibrium position (50 days in the pre-crisis period and 285 days in the post-crisis period). Hence, from the Granger causality test it can be seen that, in the pre-crisis period it was the stock market that caused the exchange rate to fluctuate (rising stock prices made the Indian companies increase their imports to meet the rising demand of the market). And in the post-crisis period, the causality among the markets improved and was prominent except for the absence of a causal link from exchange rate to stock market (exchange rate took no efforts to correct the disequilibrium in the market). The authorities, in order to restore the equilibrium faster among the markets and to encourage investments among investors after the crisis period, can pump in money into the economy by reducing the policy rates. Investors will be in a safer and advantageous position in the long-run rather than in the short-run. If investors do not wish to remain invested for a long term in the markets, then they need to be cautious about the short-run linkages among the markets and their impact on the real times investment returns.

The Indian economy showcased stability, growth and strong monetary policy due to which the economy did not stumble much. The expectations of the investors about the economy were realized when the macroeconomic variables were announced. Hence, when GDP was announced, the conditional volatility of stock market and commodity market reduced. However, the market did not behave exactly as per expectations; when

investors felt the economy was stable and growing, announcements on widening trade deficit created tension among the investors, bringing about increased volatility in commodity market and stock. The change in trade balance has a great impact on the profits of the companies (future cash flows) by influencing their raw materials cost and also the price of finished products. Besides these variables, announcement of Index of Industrial Production and Fiscal Deficit increased the conditional variance of foreign exchange market. The variables announced were against the expectations of the investors.

Hence, the volatility of the foreign exchange market increased after their announcement. Thus, investors need to consider the impacts of fundamental factors (macroeconomic variables announcement and the information content in them) prior to trading in these markets. After understanding the impact of macroeconomic variables on the conditional volatility of each market, investors need to understand the volatility of market in response to the volatility spillover from the other interlinked markets. The study about integration in the first objective established the presence of integration among the markets. In this objective, the study uses BEKK-GARCH model to model the volatility spillovers affecting the conditional volatility of each dependent market.

Results reveal that foreign exchange market is least affected (either directly or indirectly) by volatility spillover from other markets. Rather, it is primarily affected by news arising from its own market, such as the increase in the US Dollar rate due to Quantitative easing policy of the US government created changes in the exchange rate volatility and many other factors rather than the spillover of volatility from other markets. Commodity market volatility is very sensitive to news and volatilities from other markets.

Hence, investors need to be very cautious while diversifying into commodity markets. They need to take into account changes in volatilities and news from stock market, foreign exchange market and its own market too while trading and considering commodities as an investment option. Stock market volatility is also vulnerable to news and volatilities from its own market, commodity market and, to a limited extent, from foreign exchange market. The investors in stock market, should have an eye on the volatilities and on news from past stock market changes, commodity market and foreign exchange market. Besides, the policymakers should keep in mind, these relations will frame policies to tackle short-run disequilibrium in the economy (such as "Inflation targeting" in 2016 to combat rising inflation rate which affected the stock market and commodity directly and indirectly, it also affected the real rate of return on investments of investors).

5.4 SCOPE FOR FUTURE RESEARCH

- The study can be further extended by analysing the impact of announcements on the volatility linkages among the markets.

- Also one can study the linkage dynamics among the financial markets by considering bond markets.

- The researcher can further analyse the volatility dynamics of the markets by considering various other announcements (earnings, dividend, other macroeconomic variables, socio-political events, policy announcements etc.).

5.5 LIST OF PUBLICATIONS

- Ingalhalli, V., Poornima, B. G. and Reddy, Y. V., (2016). A study on dynamic relationship between Oil, Gold, Forex and Stock markets in Indian context. *Paradigm,* 20(1), 83-91.
- Ingalhalli, V., Reddy, Y. V. and Sahay, H. (2017). Integration of markets during Pre and Post subprime crisis: Evidence from India. *Amity Journal of Finance*, 2(1), 17-30.
- Paper on The impact of macroeconomic announcements on financial markets' volatility in India, is accepted by IUP Journal of Finance.

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7 APPENDIX

Table 7.1: Standardized Residuals of Stock Market

Lags	AC	PAC	Q-Stat	Prob*
1	0.001	0.001	0.0018	0.966
2	-0.037	-0.037	2.6784	0.262
3	0.015	0.015	3.1176	0.374
4	0.002	0	3.1245	0.537
5	-0.008	-0.007	3.2547	0.661
6	-0.009	-0.009	3.4107	0.756
7	0.014	0.014	3.8054	0.802
8	-0.005	-0.005	3.8539	0.87
9	0.035	0.037	6.3023	0.709
10	-0.031	-0.032	8.2615	0.603
11	-0.002	0	8.2724	0.689
12	-0.008	-0.011	8.4028	0.753
13	-0.002	-0.001	8.4087	0.816
14	0.033	0.033	10.557	0.72
15	-0.02	-0.02	11.355	0.727
16	-0.005	-0.005	11.414	0.783
17	0.048	0.047	16.036	0.521
18	0.001	-0.001	16.038	0.59
19	-0.001	0.006	16.04	0.655
20	-0.015	-0.017	16.477	0.687
21	-0.022	-0.023	17.449	0.684
22	-0.031	-0.032	19.427	0.619
23	-0.023	-0.026	20.455	0.614
24	0.004	0.004	20.485	0.669
25	-0.004	-0.005	20.517	0.719
26	0.011	0.008	20.744	0.755
27	0.002	0.004	20.75	0.798
28	-0.018	-0.019	21.379	0.809
29	-0.03	-0.026	23.141	0.77
30	0.011	0.011	23.401	0.798

Table 7.2: Standardized Residuals Squared of Stock Market

Lags	AC	PAC	Q-Stat	Prob*
1	-0.025	-0.025	1.2731	0.259
2	-0.021	-0.022	2.1462	0.342
3	-0.018	-0.02	2.8169	0.421
4	0.02	0.019	3.6378	0.457
5	-0.01	-0.01	3.8332	0.574
6	0.015	0.015	4.3025	0.636
7	0.027	0.029	5.7841	0.565
8	-0.027	-0.026	7.2277	0.512
9	0.009	0.01	7.3881	0.597
10	0.032	0.032	9.4282	0.492
11	-0.009	-0.009	9.5926	0.567
12	-0.002	0.001	9.5994	0.651
13	-0.002	-0.002	9.6039	0.726
14	0.001	0	9.6083	0.79
15	0.026	0.028	10.907	0.759
16	0.008	0.007	11.032	0.808
17	-0.02	-0.02	11.841	0.81
18	-0.002	0.001	11.846	0.855
19	0.023	0.02	12.885	0.844
20	0.024	0.024	14.037	0.829
21	-0.004	-0.002	14.072	0.866
22	0.013	0.013	14.419	0.886
23	-0.014	-0.012	14.804	0.902
24	-0.005	-0.005	14.848	0.925
25	-0.005	-0.008	14.891	0.944
26	0.022	0.019	15.852	0.94
27	-0.013	-0.01	16.185	0.949
28	-0.006	-0.005	16.247	0.962
29	0.046	0.044	20.493	0.877
30	-0.039	-0.039	23.564	0.791

Table 7.3: Standardized Residuals of Commodity Market

Lags	AC	PAC	Q-Stat	Prob*
1	0.021	0.021	0.8427	0.342
2	-0.006	-0.006	0.9071	0.558
3	0.016	0.016	1.4141	0.234
4	-0.014	-0.015	1.8103	0.404
5	0.013	0.014	2.1319	0.545
6	-0.008	-0.009	2.2528	0.689
7	0.013	0.014	2.6063	0.76
8	0	-0.001	2.6064	0.856
9	0.011	0.012	2.8612	0.898
10	-0.008	-0.009	2.9767	0.936
11	-0.002	-0.001	2.9886	0.965
12	-0.008	-0.009	3.1321	0.978
13	-0.02	-0.019	3.9204	0.972
14	0.009	0.009	4.0969	0.982
15	-0.012	-0.012	4.3883	0.986
16	-0.029	-0.028	6.0481	0.965
17	0.002	0.002	6.0539	0.979
18	0.041	0.042	9.4113	0.896
19	0.055	0.054	15.469	0.562
20	0.015	0.014	15.947	0.596
21	-0.034	-0.036	18.321	0.501
22	-0.007	-0.006	18.414	0.56
23	-0.003	-0.003	18.434	0.621
24	-0.004	-0.002	18.459	0.678
25	0.036	0.035	21.067	0.577
26	0.012	0.009	21.339	0.619
27	0.001	-0.001	21.339	0.674
28	-0.008	-0.01	21.453	0.718
29	-0.019	-0.018	22.166	0.729
30	0.02	0.022	22.933	0.736

Table 7.4: Standardized Residuals Squared of Commodity Market

Lags	AC	PAC	Q-Stat	Prob*
1	0.012	0.012	0.3	0.584
2	0.027	0.027	1.7399	0.419
3	-0.012	-0.013	2.0417	0.564
4	-0.023	-0.024	3.133	0.536
5	-0.007	-0.005	3.2211	0.666
6	-0.034	-0.033	5.57	0.473
7	0	0.001	5.57	0.591
8	0	0.002	5.5705	0.695
9	-0.019	-0.02	6.2912	0.71
10	0.034	0.033	8.618	0.569
11	0.018	0.018	9.2461	0.599
12	-0.004	-0.008	9.2761	0.679
13	-0.034	-0.035	11.588	0.562
14	0.001	0.004	11.591	0.639
15	-0.004	-0.002	11.619	0.708
16	-0.002	-0.001	11.631	0.769
17	0.001	0	11.632	0.822
18	-0.031	-0.033	13.578	0.756
19	-0.001	-0.001	13.579	0.808
20	-0.009	-0.007	13.724	0.844
21	-0.032	-0.034	15.741	0.784
22	0.04	0.038	18.895	0.652
23	-0.025	-0.023	20.173	0.631
24	0.015	0.011	20.615	0.661
25	-0.028	-0.028	22.129	0.628
26	-0.019	-0.02	22.858	0.641
27	0.001	0	22.862	0.692
28	-0.01	-0.005	23.055	0.73
29	-0.025	-0.028	24.328	0.713
30	0.01	0.009	24.51	0.748

Table 7.5: Standardized Residuals of Foreign Exchange Market

Lags	AC	PAC	Q-Stat	Prob*
1	0.011	0.011	0.2375	0.626
2	0.009	0.009	0.3994	0.819
3	0.033	0.033	2.5197	0.472
4	0.022	0.021	3.4519	0.485
5	0.027	0.026	4.8841	0.43
6	0.004	0.002	4.9189	0.554
7	0.024	0.023	6.0818	0.53
8	0.035	0.032	8.4479	0.391
9	0.017	0.014	8.9955	0.438
10	0.008	0.005	9.1086	0.522
11	0.031	0.027	10.95	0.447
12	-0.004	-0.008	10.983	0.53
13	0.02	0.017	11.757	0.548
14	0.015	0.012	12.218	0.589
15	-0.01	-0.014	12.431	0.646
16	-0.058	-0.062	19.066	0.265
17	-0.006	-0.008	19.135	0.321
18	0.039	0.038	22.123	0.227
19	0.034	0.036	24.438	0.18
20	-0.022	-0.021	25.376	0.187
21	0.004	0.002	25.401	0.23
22	-0.006	-0.01	25.463	0.275
23	-0.021	-0.02	26.374	0.284
24	0.017	0.02	26.961	0.306
25	0.017	0.019	27.543	0.329
26	0.005	0.003	27.596	0.379
27	-0.01	-0.01	27.784	0.422
28	-0.013	-0.015	28.142	0.457
29	0.014	0.014	28.539	0.489
30	0.007	0.008	28.624	0.537

Table 7.6: Standardized Residuals Squared of Foreign Exchange Market

Lags	AC	PAC	Q-Stat	Prob*
1	0.02	0.02	0.8127	0.367
2	-0.003	-0.003	0.8294	0.661
3	0	0	0.8296	0.842
4	0.039	0.039	3.8359	0.429
5	-0.018	-0.019	4.4592	0.485
6	0.021	0.022	5.3109	0.505
7	0.012	0.011	5.5763	0.59
8	0.027	0.025	7.0299	0.533
9	-0.001	0	7.0315	0.634
10	-0.002	-0.003	7.0359	0.722
11	-0.024	-0.024	8.1763	0.697
12	-0.005	-0.006	8.2171	0.768
13	-0.021	-0.02	9.0818	0.767
14	0.003	0.003	9.0984	0.825
15	0.013	0.014	9.4274	0.854
16	0.005	0.004	9.4861	0.892
17	-0.022	-0.02	10.46	0.883
18	-0.012	-0.011	10.737	0.905
19	0.003	0.005	10.757	0.932
20	-0.018	-0.017	11.369	0.936
21	-0.045	-0.042	15.303	0.807
22	0.014	0.015	15.696	0.831
23	0.008	0.006	15.826	0.863
24	-0.048	-0.047	20.318	0.679
25	-0.006	0	20.386	0.726
26	-0.014	-0.015	20.775	0.754
27	-0.008	-0.005	20.902	0.791
28	-0.029	-0.024	22.565	0.754
29	-0.025	-0.025	23.843	0.737
30	0.003	0.005	23.857	0.778

7.7: DELTA METHOD

It is used to calculate asymptotic standard error for a non-linear function of model parameters. To begin with computation, frame a standard linear model where in matrix notation it is presented as follows:

$$y = X\beta + u$$

Where y is a n x 1 vector of observations of y_t, X is the n x k matrix of independent variables u is the n x 1 vector of errors. Under asymptotic versions of Gauss – Markov assumptions, the appropriate variance matrix estimator is

$$\widehat{\sigma^2}(X'\,X)^{-1}$$

Where σ^2= (n – k)$^{-1}$ $\sum_{t=1}^{n} \widehat{u_t^2}$ and $\widehat{u_t}$ are the OLS residuals.

Now suppose that **a** is a 1 x k vector of constants and we are interested in a linear combination

$$\theta \equiv aB = a_1\beta_1 + a_2\beta_2 + ----+ a_k\beta_k$$

If $\hat{V} = \widehat{AVAR}(\hat{\beta})$ then, $AVAR\left(\widehat{\hat{\theta}}\right) = a\ \hat{v}\ a'$ and so the asymptotic standard error of θ is se $(\hat{\theta}) = \sqrt{a\ \hat{v}\ a'}$

The study now shows how the above equation is adapted to obtain a delta- method standard error for a non-linear function. The $\hat{\beta}$ is the estimator of β and $\hat{v}$ is its asymptotic variance, asymptotic standard deviation of $\hat{\theta} \equiv r(\hat{\beta})$

Se $(\hat{\theta}) = \sqrt{\hat{g}\ \hat{v}\ \hat{g}'}$

Because the delta method works off of linearizing the nonlinear function, $a \equiv \hat{g}$ where $\hat{g} \equiv g\left(\hat{\beta}\right) = (\widehat{g_1}, ---, \widehat{g_k}$ is the gradient evaluated a $\hat{\beta}$.

Hence delta method is a general method for deriving the variance of a function of asymptotically normal random variables with known variance. In this case, delta method takes the infinitely differentiable function of the data 'X' and the vector of β_s to derive a closed form solution for the standard errors of the margin.