Causal Loop Modeling of Macroeconomic Determinants of Stock Market Volatility

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Abstract

Stock market is one of the most important sources for companies to raise money. It allows businesses to be publicly traded, or raise additional capital for expansion by selling shares of ownership of the company in a public market. History has shown that the price of shares and other assets is an important part of the dynamics of economic activity, and can influence or be an indicator of social mood. An economy where the stock market is on the rise is considered to be an upcoming economy.

Stock market dynamics or volatility refers to the variation in the stock price changes during a period of time. The volatility of stock market indicators goes beyond anyone's reasonable explanations. Generally, variations in stock market are caused by the fluctuations in the performance of the economy or the macroeconomic indicators of an economy. The modeling of stock market volatility is one of the key areas of present financial research as stock market is the main determinant of economic development of a country. The present paper is intended at developing a dynamic model of macroeconomic determinants of stock market volatility via a causal loop diagramming.

Keywords: *Stock market volatility, macroeconomic determinants, causal loop diagram*

Introduction

Understanding the stock market dynamics has long been a topic of considerable interest to both policy makers and market practitioners. Policy makers on one hand are interested in the main determinants of stock market volatility and in its spillover effects on real activity, on the other, market practitioners are interested in the direct effects time-varying volatility exerts on the pricing and hedging of plain vanilla options and more exotic derivatives. In both cases, forecasting stock market volatility constitutes a formidable challenge but also a fundamental instrument to manage the risks faced by these institutions (Corradi & Distaso, 2009). The volatility of stock market indicators goes beyond anyone's reasonable explanations; industry performances, economic and political changes are among the major factors that can affect the stock market (Goonatilake&Herath, 2007).

Stock market volatility is affected both by micro and macro variables. Micro variables generally include corporate results announcements, business cycles, financial Leverage etc and the macro variables may include the indicators of country's economy, such as gross domestic production, inflation rate, foreign investment etc. Impact of macroeconomic variables is found to be more important because the stock performance of a particular company is influenced by micro variables but the macro variables drop impact on the whole stock market behavior.

Economic theory suggests that stock prices should reveal expectations about future corporate performance, and corporate profits generally reflect the

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level of economic activities. If stock prices accurately reflect the underlying fundamentals, then they should be employed as leading indicators of future economic activities, and not the other way around. Therefore, the causal relations and dynamic interactions among macroeconomic variables and stock prices are important in the formulation of the nation's macroeconomic policy. In an economy there can be a large number of macroeconomic variables which cause stock market vulnerability.

The objective of the paper is to construct the system dynamic model via causal loop diagramming for provide assistant to stock market practitioners as well as investors. The paper is divided in five sections. First section gives brief description of basic framework of the paper. Section two presents review of specific studies conducted on relationship between macroeconomic indicators and stock market volatility, and also on the basics of causal loop diagramming. In section three brief description of research objective and research methodology is presented. Fourth section is about the summary of macroeconomic determinants of stock market volatility. An attempt has been made to identify interacting causal loops for stock market returns and its macroeconomic determinants. The paper ends with fifth section by giving concluding remarks.

Literature Review

The relationship between macroeconomic variables and stock market returns is, by now, well-documented in the literature. Maysami et al. (2004) examined the long-term equilibrium relationships between selected macroeconomic variables and the Singapore stock market index. They concluded that the causal relations and dynamic interactions among macroeconomic determinants of the economy and stock prices are important in the formulation of the nation's macroeconomic policy. Aksoy & Leblebicioglu (2004) successfully implemented a rule based fuzzy logic model to forecast the monthly return of the ISE100 Index by combining technical analysis, financial analysis and macroeconomic analysis. Chowdhury et al. (2006) examined how the macroeconomic risk associated with industrial production, inflation, and exchange rate is related and reflected in the stock market returns in the context of Bangladesh. They concluded that there is relation between stock market dynamics and macroeconomic volatility. Engle & Rangel (2006) developed a model that allows long horizon forecasts of volatility to depend on macroeconomic developments, and delivers estimates of the volatility to be anticipated in a newly opened market.

Humpe & Macmillan (2007) examined whether selected macroeconomic variables influenced stock prices in the US and Japan. Adam et al. (2008) in his study found that there is co-integration between macroeconomic variable and Stock prices in Ghana indicating long run relationship. Kumar (2009) investigated the relationship between macroeconomic parameters like Exchange rate and foreign institutional investment with stock returns in India, in particular at National Stock Exchange. By using granger causality test he found that exchange rate and stock returns had no causality from either of the sides whereas stock return was found to granger cause of FII series. Ali et al. (2010) also investigated the causal relationship between macroeconomic indicators and stock exchange prices. They found co-integration between industrial production index and stock prices, and no causal relationship between macroeconomic indicators and the stock prices in Pakistan.

Gileva (2010) investigated the dynamics of oil prices and their volatilities through application of different econometrical tools as principal component analysis for finding out the fundamental factors contributing to this process. Haron & Maiyastri (2004), Kerby & James (2004), Liu & Jun (2011) and Loretan (1997) used multivariate statistical methods such as principal component analysis and discriminant analysis for determining fundamental factors of stock market trends. They concluded that such analysis can be used to reduce the effective dimensionality of other scenario specification problems.

Several authors suggested to use causal loop diagramming as the base for dynamic modeling technique due to its ability to cater a modeling framework that is causal and logically structured. Binder et al. (2004) discussed how a Causal Loop diagram can be labeled and structured incrementally in order to finally transform it into a Stock and Flow diagram. And, also described a general set of possible transformation steps and offered guidance on when to choose which step. Schaffernicht (2007) concentrated on dealing with causal links' polarity.

Then, revisited the traditional criticism of causal loop diagrams and showed a way out; and also expressed important information on causal loop diagramming.

Research Objective and Methodology

This paper is dedicated to the system dynamics modeling of macroeconomic determinants of stock market volatility via causal loop diagramming. The dynamic system modeling is conducted by using the software Vensim PLE v6.0. It is a visual modeling tool that allows to conceptualize, document, simulate, analyze, and optimize models of dynamic systems. Vensim provides a simple and flexible way of buildings imulation models from causal loop or stock and flow diagrams. This software is capable of exploring thoroughly the behavior of the model thatcan be simulated.

Macroeconomic Determinants of Stock MarketVolatility

Every stock price moves for two possible reasons viz. news about the company and news about the country. News about the company are known as the micro variables (e.g. results announcement, business cycle, financial leverage, a product launch, etc.) and news about the country are known as macro variables (e.g. a budget announcement, nuclear bombs, inflation etc.) Impact of macroeconomic variables is more important, because the stock performance of a particular company is influenced by micro variables but the macro variables drop impact on the whole stock market behavior. On any one day, there would be good stock-specific news for a few companies and bad stock-specific news for others. The news that is common to all stocks is news about macro economy.

Stock markets are barometers of the economy. It is expected that the markets and their indicators, in the form of indices, reflect the potential of the corporate listed on them, and, in the process, the direction and health of the economy. If a country's economy is performing well and expected to grow at a healthy rate, the market is usually expected to reflect that.

An extensive review of literature has been conducted for identifying the key macroeconomic variables of stock market vulnerability and the fourteen variables are selected for developing the causal model. Stock market returns (SMR) are considered as the determining variable and the selected determinants are Gross Domestic Product (GDP), Index of Industrial Production (IIP), Inflation (INF), Balance of Payments (BOP), Foreign Exchange Reserves (FXRE), Foreign Exchange Rate (FXRA), Repo Rate (RPR), Treasury Bills Rate (TBR), Prime Lending Rate (PLR), Foreign Institutional Investments (FII), Trading Volume (TRV), Market Capitalization (MCP), Crude Oil Prices (CRO) and Gold Prices (GLD).

Causal Loop Diagram

Causal modeling is a form of System Dynamics (SD). Causal modeling refers that the variables are linked by a chain of events directly on its predecessor (Halper and Perl, 2005). The real explanatory power of SD resides in the shift from the linear causal chains to closed chains of the positive and negative feedback loops. In this sense, SD defines the so called Causal Loop Diagrams (CLDs) as models of system that are abstract and simplified representations of portion of reality (Cioni, 2009).

Causal Loop Diagrams are used to document the relevant factors and the causal relationships between them. CLDs consist two items, the first are the factors or variables and second are the links connecting the factors. Any link has annotations about its polarity and delay. The polarity tells whether the dependency has positive polarity (if the cause increases, the effect will also increase compared with the situation where the cause did not change) or negative polarity (if the cause increases, the effect will decrease compared with the situation where the cause did not change) (Binder et al., 2004). In simple words, a "+" sign means that changes in first variable cause changes "in the same direction" in the second variable and a "" sign means that changes in the first variable cause a change "in the opposite direction" in the second variable. CLDs represent only the structure, the dynamics of events have been abstracted away. Basically, these are about what happens between events or variables as cause and effect.

The sources of information used in different approaches to manage the socio-economic and socio-technical problems are multiple and can be broadly categorized into three: mental, written/spoken and numerical. Mental database present with every human being is information rich and is the primary source of information. The mental database contains all information on

conceptual and behavioral information and technical fronts. Causal loop diagramming is pragmatic from its outset and has always been interested in causal beliefs that people articulate from their mental database.

Causal Loop Diagram for Stock Market and its Macroeconomic Determinants

Researcher used mental database supported by scrutinized review of researches on stock market volatility and macro economy for diagraming the CLD for modeling stock market behavior due to macroeconomic environment. The developed causal framework is presented in the figure 1. The figure, the polarity of the causal loops is indicated by the blue color at the top of the arrows. The figure shows total fifteen variables (SMR, GDP, IIP, INF, BOP, FXRE, FXRA, RPR, TBR, PLR, FII, TRV, MCP, CRO and GLD) in its silhouette. In the diagram, all the variables are interconnected by the causal loops indicating negative or positive polarity. The matrix of polarities is shown in the table 1 for giving some clarity in the figure. The logical causal relationships among selected variables are as follows:

Stock Market Returns (SMR): SMR is the main determined variable of the model. It has three positive causal links to FII, TRV and MCP with the positive polarities. As FII, TRV and MCP are basically, the indicators from stock market, they directly influenced by SMR. The rising in the stock market index results in the boost up in the number of investors, traded volume and also in the market capitalization.

Gross Domestic Product (GDP): The causal loop diagram shows that gross domestic product have six positive causal links to SMR, IIP, INF, TRV, FII and MCP. Increased GDP results into the higher employment opportunities, increased their disposable income, higher consumer spending and higher corporate profits. The increased corporate profits in turn lead to increase in the investment and production. Boom in GDP accompanied by increased money supply in an economy though enhance production of goods and services; but is likely a cause inflation rise. The increased investment opportunities may invite FII also. Thus, higher GDP is a benign factor for the economy which has an overall impact on all the companies in an economy. The market capitalization of the companies is automatically increased with the GDP growth. Further, boom in GDP also results in the increased inflation as increase in money supply is a likely cause to inflation.

Index of Industrial Production (IIP): Figure shows seven positive causal links of IIP with SMR, GDP, BOP, FII, TRV, MCP, CRO and negative link with INF. Relationships of industrial production with inflation, stock market and gross domestic product are very clear as all are the outcomes of increased money supply and higher consumer demand. Industrial production is the outcome of increasing corporates' profits and the corporates' profits are the outcomes of increased industrial production, which in turn has direct impact on the share prices, trading volume and also the investments. Figure also shows that the IIP cause to CRO, It means when industrial production increases, the demand of crude oil also increases, which results into higher crude oil prices in the international market, rising industrial production and the increased inflation.

Inflation (INF): Causality of INF are identified on the GDP, IIP, CRO, GLD and SLV with the positive polarities. Closeness in the relationship of INF with GDP and IIP is discussed in above paragraphs. The prices of crude oil, gold, silver, and inflation have cause and effect relationship. Today, commodities like crude oil, gold and silver are renowned as an effective tool to hedge against inflation. Hence, inflation causes an increase in demand for these commodities and thus leads to rise in their prices.

Balance of Payments (BOP): Figure displays the positive causal links of BOP with the variables FXRE and FII and negative causal link with FXRA. Increased international trade gives rise to currency flows in the country and improves the position of RBI to hold more foreign currency. Further, increased trade and forex reserves also attract investors from foreign countries which again strengthen the forex reserves position of the country and ultimately the value of foreign currency gets increased.

Foreign Exchange Reserves (FXRE): Forex reserves have negative causal relationship with FXRA and positive causal link with FII. Forex reserves are instruments to maintain or manage the exchange rate, while enabling orderly absorption of international money and capital flows. In brief, official reserves are held for precautionary and transaction motives keeping in view the aggregate of national interests, to achieve balance between demand

for and supply of foreign currencies, for intervention, and to preserve confidence in the country's ability to carry out external transactions. Foreign exchange reserves are important indicators of ability to repay foreign debt and for currency defence, and are also used to determine credit ratings of the nations. Thus, sound foreign exchange reserves position of the nation brings more investments from the foreign investors.

Foreign Exchange Rate (FXRA): The causal loop diagram displays the negative causal link of FXRA with IIP, BOP and FXRE. It indicates that a move in exchange rate in terms of dollar results in change in prices of imports and exports. Further, when dollar appreciates against Indian Rupee, the relative prices of exports to US increases as the import prices for US consumers gets decrease. Such a rise in exports and fall in imports reduces the current account deficit. Increased rate of foreign exchange bound to the domestic manufactures, who depends on the imported raw material or necessities to reduce their imports and the production level.

Repo Rate (RPR): The causal loop diagram shows that Repo rate has two negative causal links to the IIP and INF. When repo rate increases, interest rates on banks' deposits also increase, and in turn banks raise the interest rates on loans they offer to customers. The customers then are dissuaded in taking credit from banks, leading to a shortage of money in the economy and less liquidity. Thus, on the one hand, it controls inflation is under limits as there is less money to spend, growth suffers as companies avoid taking new loans at high rates, leading to a shortfall in production and expansion.

Treasury Bills Rate (TBR): TBR has also two negative causal links to the IIP and INF. An increase in treasury bill rate leads to higher interest rates which in turn may reduce industrial production, performance and also the reduction in general price level.

Prime Lending Rate (PLR): Causalities of PLR are identified on the SMR, GDP and IIP with the negative polarity. Economic theory says that the interest rate channel affects the demand for goods and services. Higher interest rates mean that the price of both financial and real assets - shares, bonds, property, etc. - falls and the present value of future returns drops. Further, higher interest rates also lead to a reduction in household consumption. When faced with dwindling wealth, households become less willing to consume. A rise in interest rates also makes it more expensive for firms to finance investment. As a result, higher interest rates normally curtail investment. If consumption and investment fall, so does aggregate demand. Lower aggregate demand results in lower resource utilization. When resource utilization is low, prices and wages usually rise at a more modest rate. However, it takes time before a decline in resource utilization leads to a fall in inflation. This is partly because wages do not change from month to month but more seldom than that.

Foreign Institutional Investments (FII): FII has three positive causal links to SMR, TRV and MCP, and a negative causal link to BOP. FIIs usually pool large sums of money and invest those in securities, real property and other investment assets. As bulks of their investments are in the stock market, the inflow and outflow of money by FIIs affect stock market movement significantly and also the trading volume and the market capitalization. Since, the account of balance of payments is credited by the amount of FII inflows, it has negative impact on the BOP.

Trading Volume (TRV): Causal loop diagram shows the positive causal links of TRV with SMR and MCP. Trading volume reflects the intensity of a stock, commodity or index. Volume also provides an indication of the quality of a price trend and the liquidity of a security or commodity. High volume means greater reliance can be placed on the movement in price than if there was low volume, because heavy volume is the relative consensus of a large number of participants. Increasing trading volume is the sign of growth of the stock exchange and its market capitalization.

Market Capitalization (MCP): The market capitalization also is found to have two positive causal links with SMR and FII. Market capitalization is the way to use the stock price to determine the value of a company, and to know how likely it is to grow. The investors use the figure of market capitalization to determine the size of a company. Normally, they are attracted with the growing trend of market capitalization of a stock exchange.

Crude Oil Prices (CRO): Figure depicts four positive causal links of CRO to SMR, INF, BOP and GLD. The crude oil prices and inflation are often seen as being connected in a cause

and effect relationship. As oil prices move up or down, inflation follows in the same direction. The reason why this happens is that oil is a major input in the economy - it is used in critical activities such as fueling transportation and heating homes - and if input costs rise, so should the cost of end products, which raises prices and thus inflation. Inflation causes an increase in demand for these commodities and thus leads to a rise in their prices. Hence, the profit margin of the crude oil based companies increase with ultimately influence their market performance and resulted in the growth in the overall stock market performance.

The impact of oil price on gold price could be established through the export revenue channel. In order to disperse market risk and maintain commodity value, dominant oil exporting countries use high revenues from selling oil to invest in gold. Since several countries including oil producers keep gold as an asset of their international reserve portfolios, rising oil prices (and hence oil revenues) may have implications for the increase of gold prices. This holds true as long as gold accounts for a significant part in the asset portfolio of oil exporters and oil exporters purchase gold in proportion to their rising oil revenues. Therefore, the expansion of oil revenues enhances the gold market investment and this causes price volatility of oil and gold to move in the same direction. In such a scenario, an oil price increase leads to a rise in demand and hence prices of gold. If there is hike in the prices of crude oil in international market, then the import prices for India automatically raised as India is one of the major importer for crude oil market and it will adversely affect the account of balance of payments.

Gold Prices (GLD): GLD has two positive causal links to SMR and SLV with positive polarities. Gold prices are highly dominated by the changes in the international market and fluctuate in a very intensive manner with the variations in the international commodity market. Investors are mostly interested in the assets with low price and high returns. Thus, when the gold prices are on the increasing, they generally move their investments to the stock market. Inflation channel is the best to explain the linkage between gold and silver markets. A rise in gold price leads to an increase in the general price level. When the general price level or inflation goes up, the price of silver, which is also a good, also increase. On the other hand, gold and silver prices sometimes fluctuates due to changes in demand for jewelry.

Conclusion

The paper presents a logically structured framework for interrelationship among the stock market returns and the macroeconomic determinants, which can be helpful for additional researches for developing non-linear modeling techniques such as System Dynamics, Fuzzy-Neural Networks, Fuzzy Asymmetric GARCH model, Hidden Markov Models, Wavelet Neural Networks etc. Investment in stock market is a science wherein an investor should carry out a detailed enquiry before investing. The research is aimed at developing and following a scientific approach to understand the behavior of stock market. The paper could work as an investment guide with comprehensive and in-depth knowledge on stock market investing for them. Understanding the role of economic indicators that determine market performance as well as analysis of their impact on the market, are essential skills for the finance researchers. From time to time, domestic and international economic data are released, which impact the financial markets. This research makes available a broad and wide description of macroeconomic indicators impacting stock market behavior, interpretation of the same and also the application of various techniques for analyzing the impact.

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Appendices

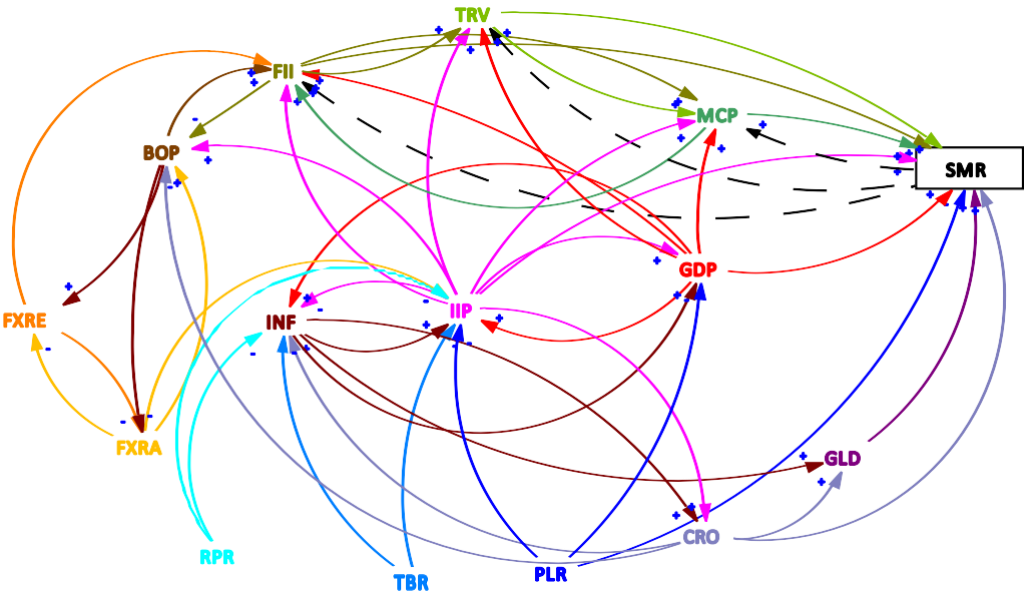

Figure 1: Causal Loop Diagram of Macroeconomic Determinants of Stock Market Volatility

Table 1: Causal Loops Matrix for all variables

	NRTS	GDP	IIP	WPI	BOP	FXRE	FXRA	RPR	TBR	PLR	FII	TRV	MCP	CRO	GLD	SLV
NRTS											+	+	+			
GDP	+		+	+							+	+	+			
IIP	+	+		-	+						+	+	+	+		
WPI		+	+											+	+	+
BOP						+	-				+					
FXRE							-				+					
FXRA			-		-	-										
RPR			-	-												
TBR			-	-												
PLR	-	-	-													
FII	+				-							+	+			
TRV	+												+			
MCP	+										+					
CRO	+			+	+										+	
GLD	+															+
SLV																

Notes: '+' and '-' shows the polarity of causal loops.