System Dynamics Modeling of Macroeconomic Determinants of Stock Market Volatility in India with Special Reference to NSEIL

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Abstract

Modeling and forecasting stock market returns and volatility is one of the key areas of present financial research because it provides a precise estimate of conditional variance process and makes a good forecast of future volatility that may help the stakeholders in obtaining efficient portfolio and accurate derivative prices of financial instruments. The system dynamics offers a useful approach for tackling environmental problems that can be conceptualized as complex, nonlinear, and multi-feedback dynamic systems. This paper aimed at developing a system dynamic model to predict stock market behavior affected due to variations in the macroeconomic indicators. It considered monthly data of stock market returns (NIFTY) of 12 years and 15 macroeconomic variables from five segments of the economy. The results of simulated model and predictions indicated that the simulated data were closer to actual data, but their behavior was linear, which was not expected in a real and dynamic economic environment.

Keywords : **causal loop diagram, Granger causality, macroeconomic variables, simulation and prediction, stock market returns**

JEL Classification Codes : C32, C53, G11, G17

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Understanding the stock market dynamics has long been a topic of considerable interest of financial practitioners, market participants, regulators, policymakers, and researchers. Volatility, an integral part of a highly liquid stock market alternating bull and bear phases, is referred to as rise or fall in stock prices. Investors interpret a rise in stock market volatility as an increase in the risk of equity investments, and consequently, they shift their funds to less risky assets. The volatility of the stock market goes beyond anyone's reasonable explanations where the industry performances as well as economic and political changes are among the major factors that can affect the stock market (Goonatilake & Herath, 2007). The stock price movements are mainly caused by fundamentals and news about companies, industries, and economies. Fundamentals and news about companies and industries include corporate results announcements, industry performance, business life cycles, business risk, financial leverage, and the performance and news about economies primarily include gross domestic product, inflation rate, interest rate, exchange rate, petroleum and gold prices, forex reserves, stock trading volume, foreign institutional investment, budget announcement, and political changes. Economists view

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that though stock performance of a particular company is influenced by micro variables, the macro variables impact the whole stock market behavior.

The volatility of stock markets has been studied for years by many researchers using several modeling techniques. Most of them view that the stock market is a chaotic, random, and nonlinear deterministic system that cannot be dealt with normal analytical techniques. Hence, to deal with this nonlinearity in the system, researchers use some parametric nonlinear models including various forms of autoregressive conditional heteroscedasticity. In the last few years, some researchers have used artificial neural networks and fuzzy logic - based methods to forecast the stock market indices. These methods allow experts to use their own experiences into developing a model. The limitation of fuzzy logic - based methods is that the experts in a particular domain can only tell the relationship between the variables, but they cannot measure the exact degree of the relationship between nonlinear fuzzy variables. Hence, to deal with such nonlinear complex situations, experts consider the system dynamic technique integrated with fuzzy logic base a better choice.

Literature Review

The relationship between macroeconomic variables and stock market returns by now is well-documented in literature. A significant research has been done to investigate the relationship between stock market returns and a range of macroeconomic variables across a number of stock markets in different time horizons. Bhattacharya and Mukherjee (2006) investigated the causal relationship between stock indices (BSE Sensex) and selected the macroeconomic variables, namely, money supply, index of industrial production, national income, inflation rate, real effective exchange rate, foreign exchange reserves, and trade balance. They found no evidence of causal linkages between stock returns and the macroeconomic variables under consideration. Corradi, Distaso, and Mele (2008) and Ali, Rehman, Yilmaz, Khan, and Afzal (2010) also rejected the hypotheses of causal relation between selected macroeconomic indicators and stock returns. Asaolu and Ogunmuyiwa (2011), while investigating the impact of macroeconomic variables on average stock prices, observed a weak relationship between average share prices and macroeconomic variables in Nigeria.

Diebold and Yilmaz (2008), in a cross - section analysis of stock market returns in 44 countries, observed a clear link between macroeconomic fundamentals and stock market volatilities. Adam and Tweneboah (2008) also, in a similar way, observed a long-run cointegrating relationship between selected macroeconomic variables and stock returns in Ghana. Kumar (2009), in a study conducted on returns at NSE, observed a causal linkage between FII and stock returns. He, however, mentioned that there existed no long-run equilibrium relationship between the stock returns. Sharma and Mahendru (2010) developed a regression model to analyze the long - term relationship between selected macroeconomic variables and stock prices at BSE, India. They observed a highly significant impact of exchange rates and gold prices and a very limited impact of forex reserves and inflation on stock prices. Naik and Padhi (2012) discovered that macroeconomic variables and the stock market indices were cointegrated, and hence, there existed a long-run equilibrium relationship between them. Tripathi and Seth (2014), Gurloveleen and Bhatia (2015), and Kotha and Sahu (2016) examined the causal relationships between the stock market performances and select macroeconomic variables in India and found a significant correlation between stock market indicators and macroeconomic factors. Das and Megaravalli (2017), in a study on the relationship between selected macroeconomic variables and NSE (India), found that the stock indices were not a leading indicator for macroeconomic variables. Bhuvaneshwari and Ramya (2018) tried to find the cointegration and causality among selected macroeconomic variables and stock indices of India. They observed that the selected macroeconomic variables had the ability to correct the disequilibrium in the price movements of the selected stock indices.

To encapsulate, a number of studies found evidences of causal relationships between macroeconomic variables and stock market performance, while some rejected the hypotheses of the relationship between these variables. Thus, the findings of studies are not substantial in drawing an exact relationship between diverse macroeconomic variables and stock prices. This entails identification of a set of macroeconomic variables that can be used for modeling stock market volatility. Hence, the objective of this paper is to construct the system dynamic model and predict the stock market behavior affected due to variations in the macroeconomic indicators.

Methodology

Systems dynamics, an analytical modeling technique developed by Sir Forrester in 1960, is concerned with the dynamic behavior of real systems. It is a rigorous method for problem identification, system description, qualitative modeling, and analysis of change in complex systems, which facilitates and can lead to quantitative modeling and dynamic analysis for the design of system structure and control (Wolstenholme, 1985). Like other methods that use a systems approach for substantive problems, system dynamics emphasizes on connections and interactions among various elements of a system, which in some sense constitute a whole. The system dynamics model combines both qualitative and quantitative aspects, and aims to enhance the understanding of complex systems to gain insights into system behavior. The qualitative aspect entails the construction of causal maps or influence diagrams in which the system structure and the interrelations between the components of a system are explored. The quantitative aspect entails the development of a computer model in which flows of material or information around the system is modeled (Dutta, 2001).

Systems dynamics is an effective tool for simulating and analyzing complex systems in which various factors are interrelated and their application range is wide. By executing the model under systems dynamics, one can grasp the relationship among factors and the flows of indicator substances not only through numerical results, but also by visualizing results with graphs. The stages of study, model building, and solving problems through the system dynamics approach includes identification of the system variables and their causal relations ; drawing causal links, causal loop diagrams and stock-and-flow diagrams ; developing dynamo equations from causal loop and stock and flow diagrams ; and simulating the developed model and predictions.

Analysis and Results

(1) System Variables and Causal Relations : The first step in developing a System Dynamics model is the identification of the key variables. This paper considers 14 key macroeconomic variables of stock market vulnerability. The description of the variables and their sources are given in the Table 1. The study considered monthly data for 12 financial years spanning from financial year 2002 - 2003 to 2013 - 2014. The causal relation between variables under consideration is determined by using the Granger causality test. Granger proposed that if a causal relationship exists between the variables, they can be used to predict each other. In general, it is the *F* - test on lagged values of a time series *X* including the lagged values of *Y* (Maddala, 2001). The mathematical presentation of the Granger causality test for a model of two variables *X* and *Y* is

$$X(t) = \sum_{j=1}^{p} A_{11,j}\, X(t-j) + \sum_{j=1}^{p} A_{12,j}\, Y(t-j) + \varepsilon_1(t),$$
$$Y(t) = \sum_{j=1}^{p} A_{21,j}\, X(t-j) + \sum_{j=1}^{p} A_{22,j}\, Y(t-j) + \varepsilon_2(t).$$

Here, p is the maximum length of the lagged observations, A is the matrix that contains the coefficients of the model (containing of each lagged values of both the variables), and ε_1 and ε_2 are the prediction errors. The magnitude of a Granger causality interaction can be estimated by the logarithm of the corresponding *F* - statistic (Geweke, 1982). The Granger causality test can be extended to *n* variables. If the hypothesis - *X* does not Granger cause *Y* - is rejected, it means *X* has causality impact on *Y* or if the hypothesis - *Y* does not Granger cause *X* - is

Table 1. Data Description

		Dependent Variable	Data Source
Independent	*NRTS*	Logarithmic returns of monthly averages of S&P CNX NIFTY (Base: November 3, 1995 = 1,000)	dbie.rbi.org.in
Variables		**(A) Real Economy Indicators**	
	GDP	Quarterly estimates of gross domestic product at factor cost (current prices) (Base: 2004 - 2005) (₹ Crore)	dbie.rbi.org.in
	IIP	Monthly index numbers of industrial production (Base: 1993 - 1994 = 100)	dbie.rbi.org.in
	WPI	Wholesale price index - monthly average (Base: 2004 - 2005 = 100)	dbie.rbi.org.in
		(B) Forex Market Indicators	
	BOP	India's overall balance of payments - quarterly (₹ crore)	dbie.rbi.org.in
	FXRE	Monthly foreign exchange reserves (₹ crore)	dbie.rbi.org.in
	FXRA	Monthly average of exchange rate of the Indian rupee (₹ per unit of USD)	dbie.rbi.org.in
		(C) Money Market Indicators	
	RPR	Repo rate	dbie.rbi.org.in
	TBR	Monthly average of implicit yield at cutoff price (per cent) on 91-day treasury bills	dbie.rbi.org.in
	PLR	Prime lending rate relates to State Bank of India (SBAR: State Bank Advance Rate)	in.reuters.com
		(D) Stock Market Indicators	
	FII	Monthly net investments by foreign institutional investors in the Indian capital market (₹ crore)	dbie.rbi.org.in
	TRV	Monthly traded volume in corporate debt at NSE (Amount traded in ₹ crore)	dbie.rbi.org.in
	MCP	Monthly market capitalization - NSE (₹ crore)	dbie.rbi.org.in
		(E) Commodity Market Indicators	
	CRO	Monthly cushing, OK WTI spot price FOB (Dollars per barrel)	eia.gov
	GLD	Monthly average price of gold in domestic market (Mumbai) (₹ per 10 g)	dbie.rbi.org.in
	SLV	Monthly average price of silver in domestic market (Mumbai) (₹ per kg)	dbie.rbi.org.in

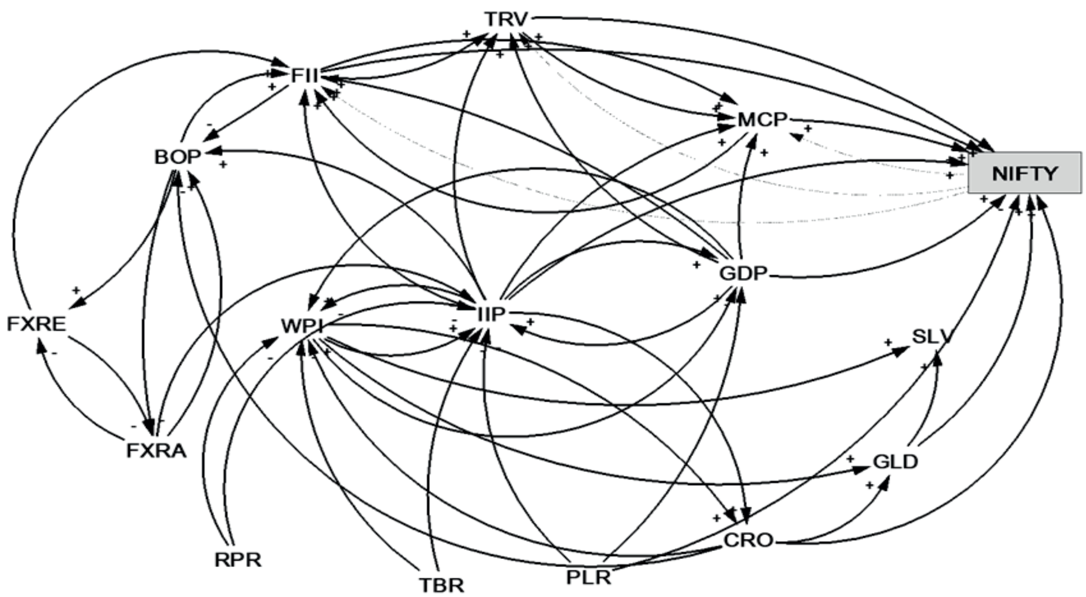
rejected, it means *Y* has causality impact on *X*, and the causality inference is unidirectional. If both the hypotheses are rejected, then it should be interpreted as bidirectional causality or feedback.

The results of Granger causality test establish only three causal relationships : (a) NIFTY Granger causes BOP, (b) NIFTY Granger causes RPR, and (c) MCP Granger causes NIFTY. All of the remaining hypotheses are not rejected at the 5% level of significance. Only the results of Granger causality are not able to develop a comprehensive causal interacted structure between stock market and the selected macroeconomic variables.

(2) Causal Loop Diagram : Causal loop diagrams (CLDs) are abstract and simplified representations of relevant factors of any system and the causal relationships between them (Cioni, 2009). The CLDs consist of two items : First, the factors or variables and second 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, Vox, Belyazid, Haraldsson, & Svensson, 2004). 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 may be mental (primary source of information present with every human being), written/spoken (previous research works), and numerical (quantitative database). The diagraming is done in Vensim® PLE v6.0 using mental (researchers' conceptual knowledge), written/spoken (reviewed research papers), and numerical information (results of Granger causality test).

The results explored by the Granger causality test for NIFTY with all the 15 explanatory variables do not show

Figure 1. Causal Loop Diagram for Stock Market and its Macroeconomic Determinants



much significant outcomes as only few of the Granger cause hypotheses are rejected and the rest are proven to be valid. As we do not observe remarkable results from the Granger causality test, written and published literature available on stock market interactions with macroeconomic indicators by scrutinized review of researches for diagramming the CLD are also considered. The developed causal framework is presented in the Figure 1. In this Figure 1, the polarity of the causal loops is indicated by black color at the top of the arrows. The logical description of causal relationships between the selected variables is as follows :

↳ NIFTY has three positive causal links (i.e., positive polarities) to FII, TRV, and MCP. As FII, TRV, and MCP are the indicators from the stock market, they are directly affected by changes in NIFTY. It indicates that a rise in stock market indices boosts the number of investors, trading volume, and market capitalization. Further, NIFTY is positively affected by GDP, IIP, FII, TRV, MCP, CRO, and GLD and negatively by PLR (Figure 1). GDP has a massive positive impact on almost all the sectors of the country. Reduced consumer spending leads to lower demand situation, which results in cutting down the production by the producers. Low industrial production results in lower corporate sales and profits, which directly affects the stock prices. So, there is a direct impact of weak IIP on sudden fall in stock prices. Increased consumer spending leads to higher demand of all products including financial products also, and in this way, inflation positively impacts the market behavior. FII, TRV, and MCP have bidirectional causal relationship. Rising prices of crude oil and gold indicates sound purchasing power of the country people.

↳ GDP has six positive causal links to NIFTY, IIP, WPI, TRV, FII, and MCP (Figure 1). It shows that growth in GDP leads to increased production opportunities, investments, and also foreign investments. Higher GDP is a benign factor for the economy, it has overall impact on trade and industry in an economy resulting into increased trade in securities and the market capitalization of companies. Boom in GDP may also result in increased money supply and inflation.

↳ IIP shows seven positive causal links to NIFTY, GDP, BOP, FII, TRV, MCP, and CRO and a negative causal link with WPI. Relationships of IIP with stock market (TRV and MCP) and GDP are very clear as these are the outcomes of increased output, higher consumer demand, better corporate performance, increased investment, and trade at the stock market. The Figure 1 shows that IIP is a cause to CRO and BOP. It is due to the fact that when industrial production increases, the demand of crude oil also increases, which ultimately results into higher crude oil prices. Further, increased industrial production may result in increased international trade, favorable BOP, and fall in inflation intensity.

➯ Causalities of WPI are observed in GDP, IIP, CRO, and GLD with positive polarities. The relationship of WPI with GDP and IIP can be understood from the discussion in the above paragraphs. The prices of crude oil and gold have a cause and effect relationship with inflation. Thus, inflation causes an increase in demand for these commodities and the increase in demand of these commodities results into a rise in inflation indices.

➯ Increased international trade gives rise to currency flows in the country and improves the position of RBI to hold more foreign currency. Increased trade and Forex reserves also attract foreign investors to invest in the country, which again improves the position of Forex reserves in the country and strengthens the value of the domestic currency (i.e., Rupee). The Figure 1 displays the positive causal links of BOP with FXRE and FII and negative link with FXRA.

➯ Official Forex reserves in a country are held for transaction and precautionary motives keeping in view the aggregates of national interests. Foreign exchange reserves are important indicators of the ability of a country to repay foreign debt and for currency defense and are also used to determine credit ratings of the nations. Sound Forex reserves position of the nation brings more investments from the foreign investors and is an important instrument to maintain the exchange rate. In the Figure 1, FXRE depicts a negative causal relationship with FXRA and a positive causal link to FII.

➯ It is commonly understood that a movement in the exchange rate results in changes in relative prices of imports and exports of goods and services, and same is the case in foreign trade and foreign investment. When U.S. dollar appreciates against Indian rupee, the relative prices of goods and services in the U.S. market fall, and the prices of goods and services imported from the United States increase. This may result in increase in Indian exports and fall in imports depending on the degree of elasticity of demand of Indian goods and services in the U.S. market. Anyways, the change in exchange rate has an impact on production of goods and services, current account balance, BOP, and the Forex reserves of the country. In the causal loop diagram (Figure 1), FXRA shows a negative causal link to IIP, BOP, and FXRE.

➯ RPR shows two negative causal links to IIP and WPI. It means when RBI increases the repo rate, interest rates on deposits and advances also increase. This, on the one hand, encourages consumers to save more and reduce consumption, and on the other hand, it dissuades people to take loans from banks, leading to a shortage of money or liquidity in the economy. Thus, it controls inflation within limits, but retards industrial production as consumption falls and companies avoid taking new loans at higher interest rates.

➯ Treasury Bills, highly liquid, and secured promissory notes are issued by the Central Government for generating funds to finance outstanding obligations. An increase in Treasury bill rate (discount rate) leads to increased interest rate, which in turn adversely affects the industrial production and controls intensity of inflation. The Figure 1 shows negative causal links of TBR with IIP and WPI.

➯ Economic theory states that the interest rate channel affects demand for goods and services. Higher interest rates mean reduction in household consumption, fall in prices of both financial and real assets (e.g., shares, bonds, and property), and also in the present value of future returns. A rise in interest rates also makes it more expensive for firms to finance investments. If consumption and investment fall, so does aggregate demand and lower resource utilization. When resource utilization is low, prices and wages usually rise at a more modest rate. The causal loop diagram shows a negative link of PLR to NIFTY, GDP, and IIP.

➯ FIIs usually pool large sums of money and invest those in securities, real property, and other investment assets. As bulk 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. As the amount of FII investment is credited in the balance of payments account, it has a negative impact on the BOP. The Figure 1 shows that FII has three positive causal links to NIFTY, TRV, and MCP, and a negative causal link to BOP.

➯ Trading volume reflects the intensity of a stock, commodity, or index. It reflects quality of a price trend and the liquidity of a security or commodity. High volume indicates greater reliance of investors in the market, positive movements in securities price, growth of the stock exchange, and its market capitalization. The causal loop diagram indicates positive causal links of TRV to NIFTY and MCP.

➯ Market capitalization is the way of using the stock price to determine the value of a company, and to know how likely it is to grow. Investors use the figure of market capitalization to determine the size of a company ; normally, they are attracted to the growing trend of market capitalization in a stock exchange. MCP is found to have two positive causal links with NIFTY and FII.

➯ Oil, one of the major inputs in an economy, is used in most of the critical activities. When input costs of oil rise, the cost of end products also rises and results into inflation. Further, inflation causes an increase in demand for oil, which in turn results into rise in oil prices, profits of oil companies, their market performance, and the growth in the stock market. The dominant oil exporting countries, with a view to invest high revenue and disperse market risk, generally invest in gold as it is an asset of their international reserve portfolios. Thus, rising oil prices (and hence oil revenues) may have implications for the increase of gold prices. Further, the hike in crude oil prices in international market results in rising bill of oil-importing countries and also the rising negativity in the balance of payments account. The causal loop diagram shows three positive causal links of CRO to NIFTY, WPI, and GLD, and a negative link to BOP (Figure 1).

➯ Investors are mostly interested in assets with low prices and high returns. When gold prices increase, investors divert their investments to the stock market. This is indicated by a positive causal link of GLD with NIFTY in the causal loop diagram.

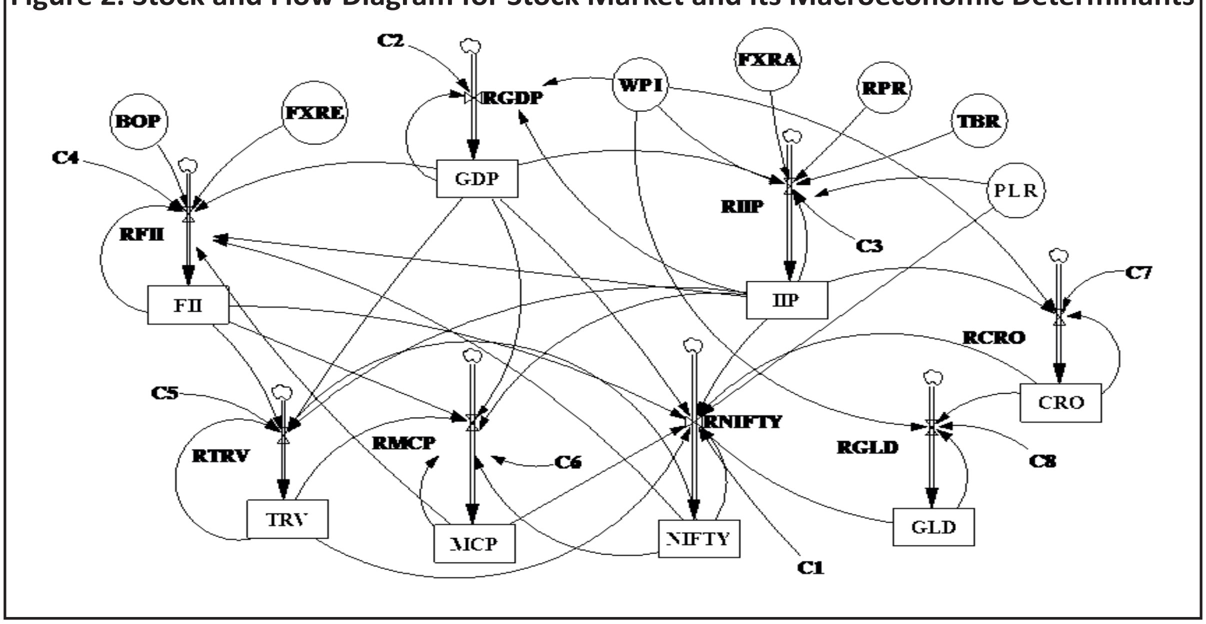
(3) Stock and Flow Diagram : A stock-and-flow diagram (SFD) represents systems where the external world exerts its influence on the model through either exogenous variables or levels' initial values as opposed to endogenous variables that form the heart of the model. SFDs can be used to model differential equations of any order that are simulated in continuous time with difference equations by fixing an initial time, final time, and a time step. In this way, the model developer can obtain the characteristic time trajectories of all endogenous variables, trajectories that can be compared with available data, measured on the portion of reality that was tried to model (Cioni, 2009). In simple words, SFD is nothing but an elaborate diagram of a causal loop diagram, which clearly shows the level variables, rate variables, and auxiliary & exogenous variables. Therefore, it is quite helpful in writing the dynamo equations (Chaturvedi, Singh, Manmohan, Gaur, & Mishra, 2001). In the system dynamics modeling process, model developers are required to define the types of variables needed in order to characterize conservative material flows and non - conservative information flows in graphical models that represent graphically differential equations by using level variables, rate variables, auxiliary variables, constants, and flow arcs organized into a consistent network. The components of a SFD are as follows :

- **Level Variables :** The level variables represent the accumulations within the system. Levels are the present values of those variables that have resulted from the accumulated difference between inflow and outflow. These describe the condition of the system at any particular instant of time, and are denoted by a rectangle ( ) (Figure 2). The levels are also known as stocks, state variables, and compartments. They start with some initial values and are thereafter changed only by flows into and out of them. The Figure 2 shows the corresponding SFD with eight level/stock variables, that is, NIFTY, GDP, IIP, FII, TRV, MCP, CRO, and GLD. As PLR is not influenced by any of the selected variables, it is not considered as a level variable in the diagram.

- **Flow Variables :** These are also known as rate variables ; defined as the present (instantaneous) flow between the level variables in the system. The rate variables correspond to activity, while the level variables measure the resulting state to which the system has been brought by the activity. The flow rate variables are determined by the level variables of the system according to rules defined by the decision functions. Accordingly, the rates determine the levels, and tell how fast the levels are changing. The rate variable neither depends on its own past values and the time interval between computations, nor on the other rate variables. No flow rate variable can be measured instantaneously. All instruments that purport to measure rate variables actually require time for their functioning. They measure average rate over some time interval. At zero rate also, there is some value of level variable. These are denoted by an arrow with tap ( ) (Figure 2). The diagram shows eight rate variables, namely, RNIFTY, RGDP, RIIP, RFII, RTRV, RMCP, RCRO, and RGLD.

- **Auxiliary Variables :** Auxiliary variables are those which influence level variables (via rate variables), but not influenced by any other variables. These are expressions involving stocks/flows at current time, and are denoted by the circles ( ) (Adding or eliminating an auxiliary variable does not change the mathematical structure of the model system. Figure 2 shows seven auxiliary variables, namely, WPI, BOP, FXRE, FXRA, RPR, TBR, and PLR.

Figure 2. Stock and Flow Diagram for Stock Market and its Macroeconomic Determinants



↳ **Source/Sink :** Source or sink represents systems of levels and rates outside the boundary of the model. Sink, symbolized by cloud (☁), is placed where flows terminate outside the system.

↳ **Constants :** Many numerical values that describe the characteristics of a system are considered constant, at least for duration of computation of a single model run. The Figure 2 shows the eight constant variables in the model. These are indicated by $C1$ - $C8$.

(i) Dynamo Equations : The concept of dynamo equations was originally developed by Pugh (1976). These are the first dynamics simulation language that tells how to generate the system conditions for a new point in time, given the conditions known from the previous point in time. The dynamo equations of the model are evaluated repeatedly to generate sequence of steps equally spaced in time. Level equations are rate equations that generate the levels and rates of the basic model structure. In addition, auxiliary supplementary and initial value equations are also used for model development. In dynamo equations, time represents itself in the following ways :

J = Time level calculated at one time interval before,
K = Time level calculated at the present,
L = Time level calculated at one time interval after, and
DT = the length of the time interval between J and K.

↳ **Level Equations :** In our model, there are eight level equations to find the accumulated value corresponding to each level or stock variable :

$L\ NIFTY.K = NIFTY.J + DT \times RNIFTY.JK$ ....(1)
where Initial $NIFTY$ = 1,000 and $RNIFTY$ = Rate of $NIFTY$

$L\ GDP.K = GDP.J + DT \times RGDP.JK$ ....(2)
where Initial GDP = 431,000 and $RGDP$ = Rate of GDP

$L\ IIP.K = IIP.J + DT \times RIIP.JK$ ....(3)
where Initial IIP = 147 and $RIIP$ = Rate of IIP

$L\ FII.K = FII.J + DT \times RFII.JK$ ....(4)
where Initial FII = 800 and $RFII$ = Rate of FII

$L\ TRV.K = TRV.J + DT \times RTRV.JK$ ....(5)
where Initial TRV = 4 and $RTRV$ = Rate of TRV

$L\ MCP.K = MCP.J + DT \times RMCP.JK$ ....(6)
where Initial MCP = 445,300 and $RMCP$ = Rate of MCP

$L\ CRO.K = CRO.J + DT \times RCRO.JK$ ....(7)
where Initial CRO = 17 and $RCRO$ = Rate of CRO

$L\ GLD.K = GLD.J + DT \times RGLD.JK$ ....(8)
where Initial GLD = 4,000 and $RGLD$ = Rate of GLD

The above equations represent the level equations for each level variable at *K*th time instant, which are equal to the level variables at *J*th time instant and the increments in them. The increments in the level variables can be determined by the rate of prevalence between *J*th and *K*th time instants and the time increment, which is *DT*. To start the simulation, it is necessary to give some initial conditions. Hence, initial values for all the level variables are given in the below equations.

(ii) Flow - Rate Equations : Flow - rate equations, also known as rate equations, define the rates of flow between the levels of a system. These are basically "decision functions" that are evaluated from the existing value of the level in the system, which vary often, including the level from which the rate comes and the one into which it goes. The rates, in turn, cause the changes in the level. A rate equation is evaluated at time *K* to determine the decision governing the rate of flow over the forthcoming interval *KL*. As rate equations depend only on the value of levels at time *K*, these are evaluated independently of one another within any particular time step, and hence determine an immediately forthcoming action. Further, because they depend on the values of the levels, the group of rate equations is better to put after the level equations. In our model, there are eight rate equations corresponding to each of the flow rate variables :

$$RNIFTY.KL = C1 + 0.069 \times GDP.K + 0.070 \times IIP.K - 0.007 \times PLR.K + 0.028 \times FII.K + 0.035 \times TRV.K + 1.056 \times MCP.K + 0.054 \times CRO.K + 0.224 \times GLD.K \quad \text{......(1)}$$

$$RGDP.KL = C2 + 0.408 \times IIP.K - 0.553 \times WPI.K - 0.074 \times PLR.K \quad \text{......(2)}$$

$$RIIP.KL = C3 + 0.727 \times GDP.K + 0.242 \times WPI.K - 0.076 \times FXRA.K - 0.057 \times RPR.K - 0.017 \times TBR.K - 0.040 \times PLR.K \quad \text{......(3)}$$

$$RFII.KL = C4 + 2.210 \times NIFTY.K + 0.467 \times GDP.K + 0.399 \times IIP.K + 0.191 \times BOP.K + 0.299 \times FXRE.K + 2.856 \times MCP.K \quad \text{......(4)}$$

$$RTRV.KL = C5 + 0.560 \times NIFTY.K + 0.766 \times GDP.K + 0.431 \times IIP.K + 0.170 \times FII.K \quad \text{.....(5)}$$

$$RMPC.KL = C6 + 0.812 \times NIFTY.K + 0.235 \times GDP.K + 0.080 \times IIP.K + 0.043 \times FII.K + 0.037 \times TRV.K \quad \text{......(6)}$$

$$RCRO.KL = C7 + 0.123 \times IIP.K + 0.956 \times WPI.K \quad \text{......(7)}$$

$$RGLD.KL = C8 + 1.131 \times WPI.K + 0.202 \times CRO.K \quad \text{......(8)}$$

In the above equations, the values of the multipliers (standardized coefficients) of level and auxiliary variables are calculated by using multiple linear regression technique.

(iii) Auxiliary Equations : The auxiliary equation is a kind of great help in keeping the model formulation in close correspondence with the actual system, as it can be used to define separately, the many factors that enter decision-making. The auxiliary equations are evaluated at the time *K*, after evaluating the level equations for time *K*, because the rate for which they are the part, they make use of present values of levels. Further, the auxiliary equations are evaluated before the rate equations, because their values are obtained for substitution into the rate equation. Unlike the level and rate equations, the auxiliary equations cannot be evaluated in an arbitrary order. For the purpose of simulation, we used monthly data series of all the auxiliary variables.

(4) Simulation and Predictions : Simulation is a tool that has become widely accepted to analyze large and complex real-world situations that cannot be solved by conventional quantitative analysis (Srijariya, Riewpaiboo, & Chaikledkaew, 2008). Simulation basically allows "what-if" analysis to the researchers and policy/decision makers. It is the last phase of system dynamics modeling. In this phase, the behavior of the simulation model is compared qualitatively and quantitatively with the behavior of the system of interest's reference mode. The reference mode represents either an empirical trajectory of one or more state variables through time or a hypothesized mode of behavior that the model builders would like the real system to achieve. In the case of basic science, a system dynamics model is judged to be verified if the simulation model is able to replicate the actual pattern of the system of interest in a qualitatively and quantitatively reasonable fashion. At a qualitative level, the model may be verified if the magnitude and the timing of turning points of the state variables correspond closely with the behavior of the real system. The results of simulation with predictions are presented in Figures 3–10. In these figures, the time range covers 192 months, which includes 144 months (from April 1999 to March 2011) of training and model development, and the remaining 48 months (from April 2011 to March 2015) for predicting behavior of NIFTY. The results reveal that the simulated data for all the level variables are much closer to actual data.

Figure 3. Simulation Results and Predictions for *NIFTY*

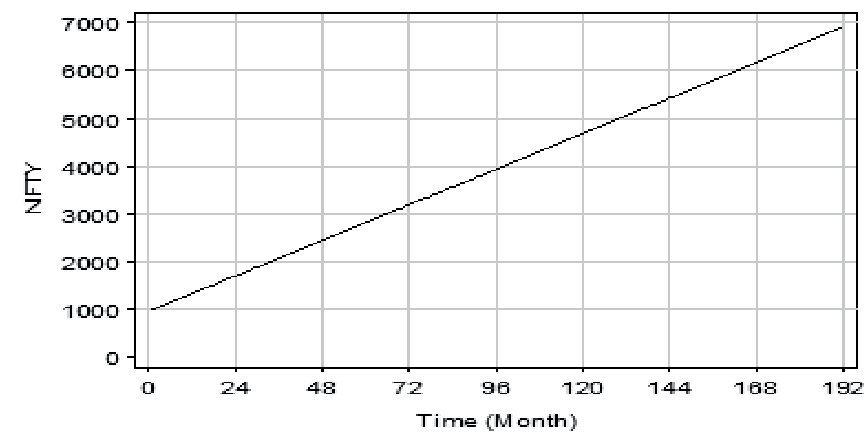


Figure 4. Simulation Results and Predictions for *GDP*

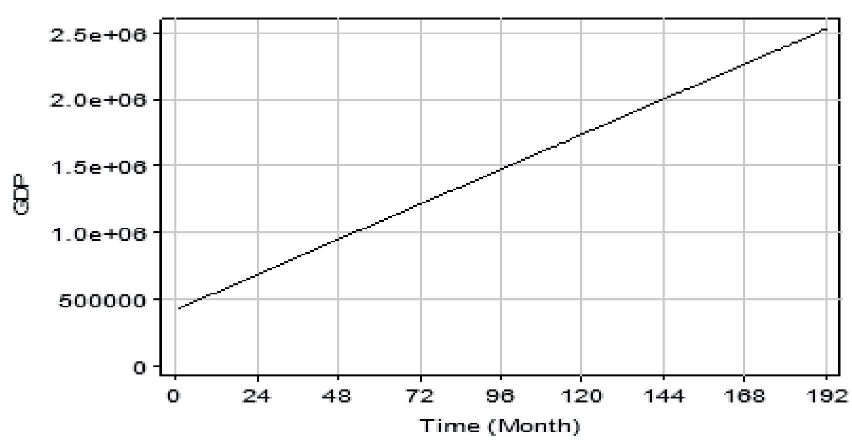


Figure 5. Simulation Results and Predictions for *IIP*

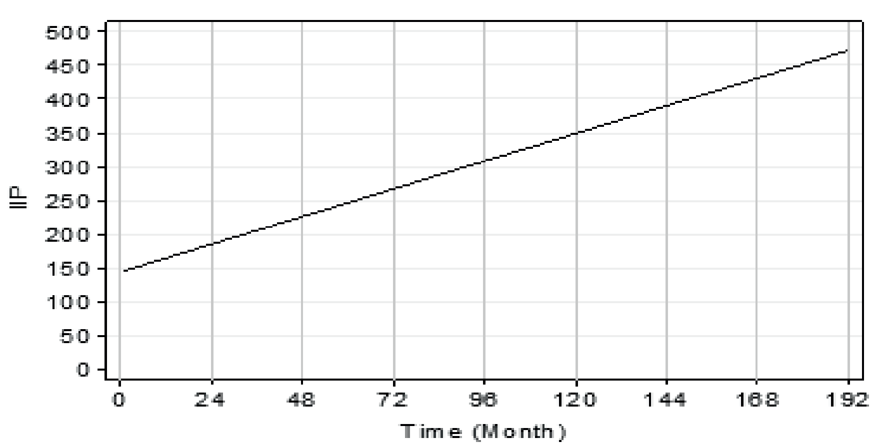


Figure 6. Simulation Results and Predictions for *FII*

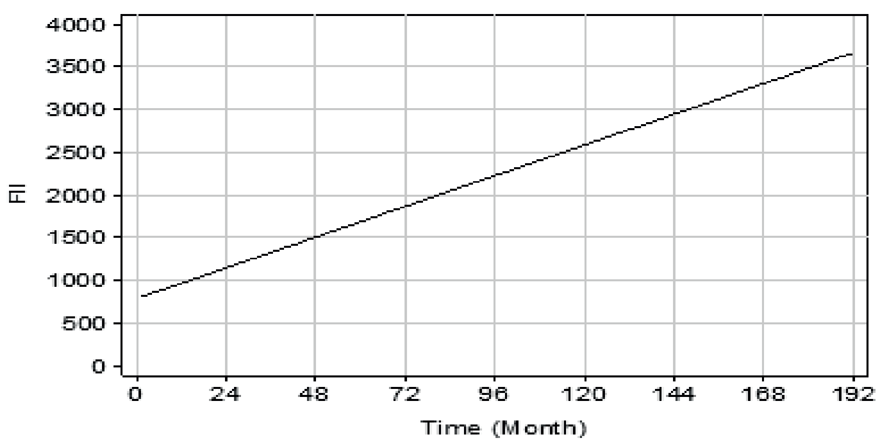


Figure 7. Simulation Results and Predictions for *TRV*

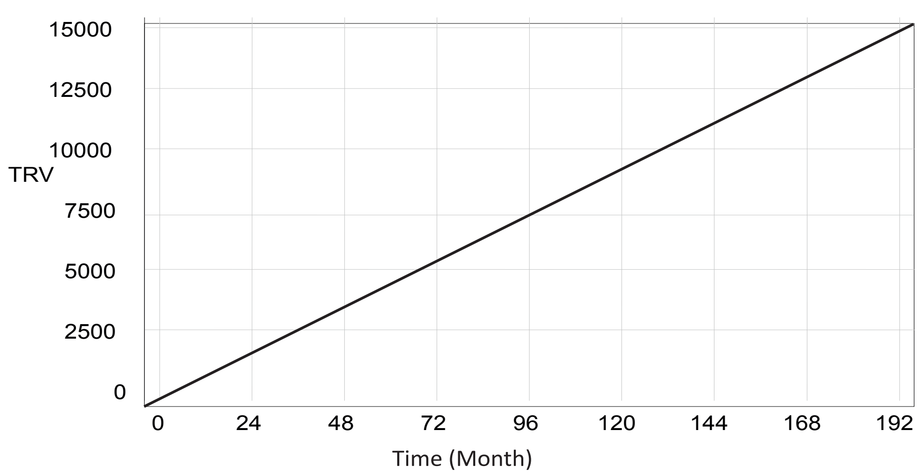


Figure 8. Simulation Results and Predictions for *MCP*

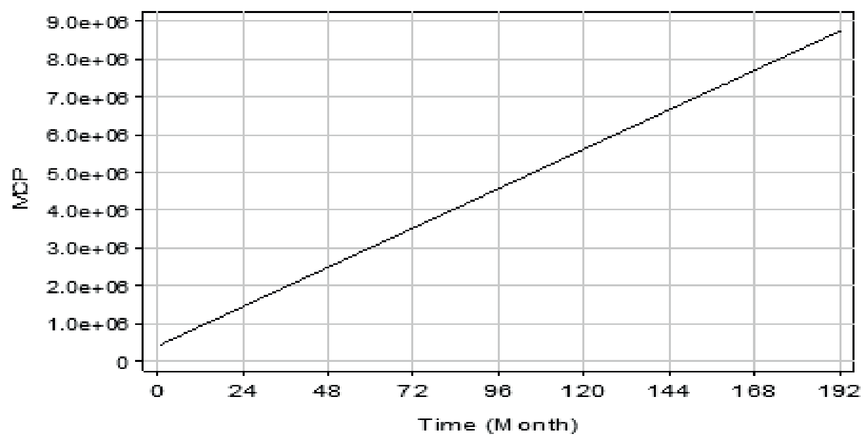


Figure 9. Simulation Results and Predictions for *CRO*

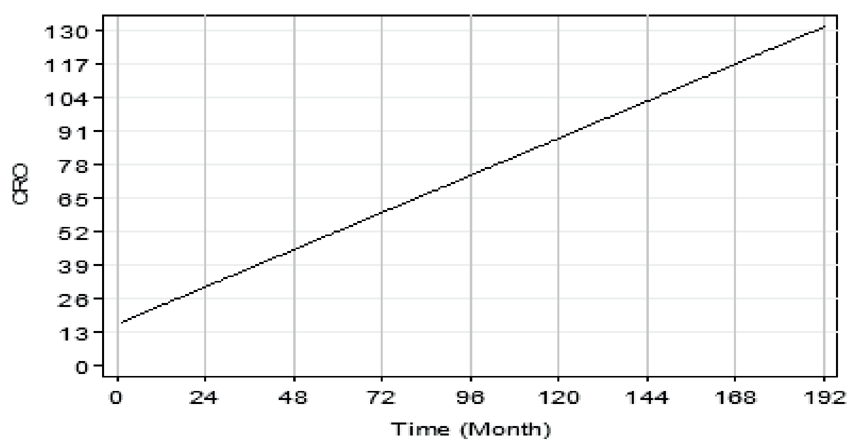
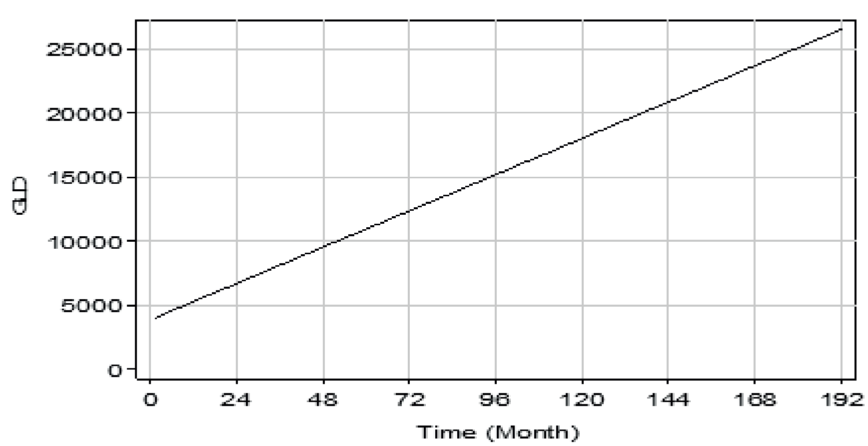


Figure 10. Simulation Results and Predictions for *GLD*



Conclusion

Statistical techniques are methods for analyzing collected data, rather than for deriving conceptual models of the interrelationships between the variables of interest. Although such techniques might be useful in the analysis of data, it is difficult to use them for driving the development of a complex system model. The system dynamics offers a useful approach for tackling environmental problems that can be conceptualized as complex, nonlinear, and multi-feedback dynamic systems. The results of simulation and predictions for all the level variables (namely, NIFTY, GDP, IIP, FII, TRV, MCP, CRO, and GLD) drawn using SD approach indicate that though the simulated data are closer to actual data, their behavior is linear, which is not expected in a real and dynamic economic environment.

Implications and Scope for Further Research

This study presents an interrelationship among the stock market returns and the macroeconomic determinants in a logical and structured way, which is quite helpful for policy makers, market practitioners, and researchers. Although the study is carried out with a number of time and information limitations, it involves a lot of painstaking efforts in dealing with various aspects related to the problem under study. We feel that there is scope for further research, improvements, and additional insights. Over time, as the database expands, further studies may use some other macroeconomic variables or microeconomic aspects related with problems or may incorporate views and opinions of stock market practitioners, investors, dealers, etc. in the study.

Limitations of the Study

Every empirical work has to pass through certain limitations. This study also has its own limitations. Few unavoidable limitations of the study are : (a) the study does not consider the views and opinions of the stock market practitioners and investors, thus, it carries all the limitations inherent with the usage of secondary data, (b) for compiling monthly data, some adjustments are made because data on some variables were available only on a quarterly basis, (c) the study is limited only to the macroeconomic determinants of the stock market volatility ; it does not consider the microeconomic determinants of the stock market volatility.

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