CHAPTER 1

INTRODUCTION

1.1 Preamble

Volatility is an established phenomenon in emerging markets, and India is no exception. The Bombay Stock Exchange (BSE) trading system, which was initially both Order and Quote driven, transformed to only Order driven, wherein the buyers and sellers transact directly with each other. The growth of the market has been hampered by a relatively high degree of volatility and illiquidity [77]. In the two US markets of New York Stock Exchange (NYSE) and National Association of Securities Dealers Automated Quoted System (NASDAQ), specialists/market-makers respectively, play a vital role in their structure in trading, and bring in stability to the market [45]. However, market-makers are absent in the Indian markets [77], which is perhaps one of the key reasons for the prevailing high volatility. This dissertation explores agent based Artificial Stock Markets (ASM) as a tool for analyzing the behavior of market participants at the BSE, and suggests a suitable market making model to regulate the volatility. It is shown that such models can contribute to provide the link between micro and macro behavior of the market. The financial market of BSE is analyzed using intelligent agents, their behavior modeled in terms of algorithms.

The BSE, located on Dalal Street, Mumbai is the oldest stock exchange in Asia. Trading volumes in the equity segments of the stock exchanges have witnessed phenomenal growth over the last two decades, having explosively grown from INR 9.7 trillion(2002-03). Similarly, market capitalization of securities available for trading on the equity segment of BSE witnessed enormous growth at over INR 50 trillion each [126]. In 2010, the average volume of business conducted on the BSE was approximately INR 100 billion each month. The number of shares traded each month on the BSE is in the range of 40 to 50 million. The equity market capitalization of the companies listed on the BSE was INR 75 trillion as of December 2010, making it the...
4th largest stock exchange in Asia and the 8th largest in the world [127]. Though many other exchanges exist, BSE and the National Stock Exchange (NSE) of India account for the majority of the equity trading in India [77]. In the United States, NASDAQ index has come to symbolize the new economy or technology stocks. Comparing the movements of BSE and NSE with NASDAQ, in the early part of the decade, it is seen that their stock price movements were synchronized. This is not surprising since the IT sector companies showed drastic improvement in market capitalization in Indian markets during this period. However, an analysis of the second half of the last decade (from the period January 2005 onwards), reflects a distinct divergence of Indian markets from NASDAQ, with high volatility in the SENSEX (BSE index BSE 30). Figure 1 compares the index volatility of the Indian stock markets namely, BSE (SENSEX) and NSE (NIFTY) with NASDAQ for the years from 2001 to 2010. The X-axis represents the trading days from Jan 2001 to Dec 2010. Y-axis represents the variance of the indices on a 30-day window. We observe that the volatility of NSE and BSE have been very high compared to that of the NASDAQ over this period and this scenario may persist in the BSE, as was demonstrated using an agent based model [59]. Volatility is calculated as standard deviation of the daily returns for the respective period.

![Figure 1: Volatility of the Indian Stock Markets Vs NASDAQ](image-url)
Further, foreign fund inflows through Foreign Institutional Investors (FII) have fueled a rally in the Indian stock market, with volume increasing significantly in the last decade. Strong risk adjusted returns of the Indian market have led FIIs to make more allocations to India. Foreign fund investments of INR 120 billion (Dec 2010) have powered the benchmark index nearly 20 percent higher. Since FII do only delivery based trades, they are perceived to be infallible in their assessment of Indian markets. However, when other markets become attractive, the market volatility in India increases due to the FII exiting [41]. Yet another relevant aspect is that many listed securities on the BSE are not traded actively and are therefore illiquid. The percentage of companies traded on BSE was quite low at 34.5% [77]. Volatility invariably makes the BSE more risky for investing [41,59]. In the two US markets of NYSE and NASDAQ, specialists/market-makers respectively, play a vital role in their structure in trading, and bring in stability to the market [45]. However, market-makers as an institution, are absent in the Indian markets. Absence of an electronic market maker in the Indian markets therefore, is perhaps one of the key reasons for the prevailing high volatility.

Financial theories have long been dominated by the Efficient Market Hypothesis (EMH), which states that market prices fully reflect all available information [30], and that efficient markets do not allow investors to earn above average returns without accepting above-average risks [79]. However, it has been now established that humans have limited ability to adapt optimally to complex environments and the importance of bounded rationality has been highlighted [109]. In addition, individual investors are prone to biases in judgment and various heuristics are used thereby leading to anomalies. Conventionally, the behavior of traders has been described mathematically, and the market system is evaluated at equilibrium conditions. The dynamics of price formation however, is influenced by the large diversity in decision making methods, interpretation of available information, learning capacity, attitude to risk, time horizon, and the market microstructure i.e. the organization of the specific market where the traders operate.
In recent years, the agent-based approach to economic and financial analysis has grown into an important research field for developing and understanding the complex patterns and phenomena that are observed in economic systems. ASM are models for studying the link between individual investor behavior and financial market dynamics. They are often computational models of financial markets, and are usually comprised of a number of heterogeneous and boundedly rational agents, which interact through some trading mechanism, while possibly learning and evolving. These models are built for the purpose of studying agents’ behavior, price discovery mechanisms, the influence of market microstructure, or the reproduction of the stylized facts of real-world financial time-series (e.g. fat tails of return distributions and volatility clustering). A similar bottom-up approach has been utilized in agent-based computational economics (ACE) [63,64,65,71,114] – which acknowledges the distributed nature of trading in financial markets by computational study of economies modeled as evolving systems of autonomous interacting agents that correspond to the trading parties. A methodology analogous to agent-based modeling has also been used in the physical sciences, for example the microscopic simulation – a tool for studying complex systems by simulating many interacting microscopic elements [67]. The agent-based computational economics and the micro-simulation approaches emphasize the need to represent traders as individuals and to study the way macro features emerge from individual interaction. Agent-based models offer the possibility to transparently model behavioral issues and to study in this way the effect of agents’ behavior on the market prices. Further, in agent-based ASM models, prices can be endogenously formed by the system itself as the result of interaction of market participants. By using agents for studying market dynamics, heterogeneous, boundedly rational, and adaptive behavior of market participants can be represented and its impact on market dynamics can be assessed. Using the methodology of agent based modeling, extensive studies of US markets have been carried out [7,63,65,67,90], whereas no such work has been seen published for the BSE.
1.2 Research Objectives

This research work focuses on a study of BSE employing agent based ASM models. The research objectives are stated as follows:

(a) Analyze the behavior of market participants in the BSE employing suitable agent based ASM so as to evolve an explanatory model which would enable the study of influence of traders’ decision on the market dynamics, thereby linking the micro and macro behavior of the market.

(b) Explore the role of market maker for possible regulation of volatility in the BSE and suggest a suitable model employing agent based computational approach.

1.3 Research Methodology

Several approaches exist to study and understand market dynamics. Theoretical studies aim to find explanations through analytical models; empirical research analyses historical data to find correspondence between various factors; and experimental studies (closely related to the behavioral finance) focus on analyzing the trading behavior and its consequences on the market dynamics. In this thesis, the market microstructure identifying the relevant aspects of a stock market is analysed first, followed by study of market dynamics. The prevailing structure of BSE is explored next. After having gained insight into the workings of real markets, a literature survey on ASM is carried out and an overview of several ASM prepared.

Using a suitable agent based ASM model chosen during the survey, the Indian stock market (BSE selected for the study) is analysed in order to study the market dynamics, arising from the interaction of individual agents. The behavior bias of investors in the BSE is then analysed with a view to arrive at a possible proportion of various categories of investors who populate the Indian stock market. Behavioral biases of individual investors have been modeled and studied in [75]. It has been demonstrated that agent-based ASM have been potentially able to fully bridge the gap between individual investor behavior and aggregate market phenomena, by allowing the modeler to specify the behavior of market participants, to implement various market mechanisms, and to
analyze the resulting asset prices. An ASM has been used as a tool to generate and test various behavioral hypothesis and theories. Similarly, employing the incremental approach according to which an existing computational model is first replicated, and then, behavioral bias is introduced into the model [75] and studied. By comparing the results of the original model with the results of the incremented model, implications of the newly introduced biased behaviors in the BSE have been studied. The incremental approach is built upon the ASM model developed by Levy et al [71], also known as the LLS model and modified by Lovric M.[75].

The next step is to explore the role of a market-maker for the possible regulation of volatility observed in BSE. It will be tested whether introduction of a market maker in the BSE would indeed regulate the volatility and consequently prove to be a step in the direction towards a more matured and stable market.

As reflected by the research objective, agent-based computational approach has been chosen to make the study. Agent-based simulation is chosen in the experiments since it gives the freedom to manage various parameters, and the possibility to observe traders’ behavior. This in turn helps to study the influence of traders’ decision on the dynamics.

1.4 Outline of the Thesis

The structure of the thesis is directed by the objectives of the thesis stated above. In Chapter 2, an overview is given on the structure of stock market organizations and the behavior of market participants. Important factors that should be considered when modeling markets are spelt out. The trading behavior of market participants, such as investors, brokers and market-makers is analyzed, and results in taxonomy of real markets and market participants. Further, an overview of approaches used to describe and understand market dynamics is presented. The analytical, empirical and experimental research conducted in this area is analyzed, compared and the motivation for choosing to apply the agent-based computational approach is emphasized. In the latter part of Chapter 2, the aspects of investor behavior biases are explored:
overconfidence, sentiments (pessimism and optimism), self-attribution bias, loss aversion, regret, recency and primacy effects etc.

Agent-based artificial financial markets are potentially able to fully bridge the gap between individual investor behavior and aggregate market phenomena, by allowing the modeler to specify the behavior of market participants, to implement various market mechanisms, and to analyze the resulting asset prices [8,63,71,75].

In Chapter 3, a survey is carried out on several ASM from the literature. The aspects that these ASM represent and model are investigated. The analysis conducted here helps in identifying a suitable model to represent the BSE.

In Chapter 4, a survey is carried out on the ASM that model behavior bias of investors.

In Chapter 5 the ASM model so selected to model the BSE in Chapter 3, will be run with forward testing, i.e. by taking as input the actual data from the BSE, so as to explore the aspects of volatility prevailing in Indian markets.

In Chapter 6, the behavior of various categories of fundamental, technical and uninformed investors populating the BSE is analysed, and an attempt is made to arrive at a possible proportion of their distribution, which may also explain the causes for the high volatility prevalent. The behavioral aspects of sentiments, overconfidence, loss aversion etc are built into the model.

In Chapter 7, the role of a market-maker is studied; the important models are discussed and the effect of introduction of a market maker in the BSE to regulate the volatility is analyzed. This is illustrated by replicating the market-maker models given in the Extended Glosten and Milgrom model [26].

Finally, Chapter 8 concludes the work, with suggestions for further research.
1.5 Highlights of this Thesis

1.5.1 ASM Model for BSE

(a) Identifying relevant factors of a stock market for its analysis, including behaviour bias of investors.
(b) Studying existing ASM and evaluating with real stock markets.
(c) Preparing an up to date taxonomy of ASM.
(d) Developing an ASM for modeling the BSE.
(e) Forward testing (by taking as input the actual data from the BSE) [65] on the model so chosen and arriving at various statistical properties of the BSE.
(f) Analyzing the dynamics of investor interaction in BSE using the ASM model.
(g) Demonstrating that agent based ASM can contribute to provide the link between micro and macro behaviour of the BSE.

1.5.2 Investor Behavior in BSE

(a) Analyzing the behavior of market participants.

(b) Studying the investor behavior biases.

(c) Arriving at a possible proportion of various categories of investors populating the Indian stock market and comparing with the US markets of NYSE and NASDAQ.

1.5.3 Market Maker Model for BSE

(a) Exploring the role of a market-maker for the possible regulation of volatility observed in BSE, in the sense that the market price perturbations are in direction with the intrinsic value.

(b) Suggesting a suitable market maker model for the BSE.