CHAPTER 7

AN AGENT BASED MODEL OF A MARKET MAKER FOR THE BSE

7.1 Introduction

Emerging stock markets across the globe are seen to be volatile and also face liquidity problems, vis-à-vis the more matured markets of the developed world [18]. In order to make markets more efficient and an attractive avenue for international investors, regulators are required to adopt a suitable market making design. The Indian stock markets, being an emerging market, face relatively high volatility when compared to that of the other matured developed stock markets like NASDAQ and NYSE [77]. Higher the volatility of a market, higher is the risk involved for investors. Unlike the stock markets of NASDAQ and NYSE, absence of an electronic market maker in the Indian markets appears to contribute towards the prevailing high volatility and this issue is investigated in this chapter. The electronic market makers prevalent in the developed markets are generally seen to have a stabilizing effect on the market, apparently reducing volatility to a great extent. In order to make markets more efficient and an attractive venue for international investors, regulators are required to adopt a suitable market making design [26].

7.2 Overview of the Chapter

This chapter demonstrates the suitability of Extended Glosten and Milgrom (EGM) market maker model as the electronic market maker for the BSE. The market maker in the EGM model quotes the bid and ask prices based on the orders placed by the pool of traders. It is shown that in the EGM model, the market maker’s quotes are comparable to the fundamental value of the stock and any sudden change in the fundamental value (in case of jumps) causes fluctuations in the quotes that are very quickly resolved, thereby bringing stability in the market. The experiments done on the real data from BSE demonstrate that, this model can be used as the market maker in the context of Indian
This would induce more stability and reduce the volatility, thereby making the market safe for genuine investors. In the ensuing part of this chapter, the role, functions and the structure of market makers in general are discussed initially, followed by a discussion on ASMs with models of market makers and finally a model for a market maker in the BSE is suggested.

### 7.3 Trading in Stock Exchanges

Trading in stock markets take place either on the basis of the auction system on a trading floor which is order driven (customer driven), or a broker-dealer market which is quote driven (dealer driven). Every one of the world’s stock markets uses one of the two trading systems or a hybrid of both [45]. While the over the counter market served by a computerized network, the National Association of Securities Dealers Automated Quoted System (NASDAQ) is an example of the broker-dealer market which is quote driven or dealer driven, an example of an auction market which is order driven is New York Stock Exchange (NYSE). The BSE and the NSE is an order driven market with fully automated screen based trading system [77].

### 7.4 Market Makers

In modern financial markets, market-makers (or dealers) are agents who stand ready to buy and sell securities. The rest of market participants are therefore guaranteed to always have a counter party for their transactions. This renders markets more orderly and prices less volatile. Market-makers are remunerated for their services by being able to “buy low and sell high”. Instead of a single price at which any trade can occur, dealers quote two prices – a “bid” (dealer’s purchase, customer’s sale) and an “ask” (dealer’s sale, customer’s purchase). The ask is higher than the bid, and the difference between the two is called the spread – the dealer’s source of revenue. In the two US markets of NYSE and NASDAQ, market-makers play a vital role in their structure in trading. The NYSE is an auction-based market where traders meet on the floor of the exchange, using person-to-person, telephone orders or electronic orders. The NASDAQ, on the other hand, is strictly an electronic exchange. Market makers often are known by other names. Market makers who have the obligation to commit capital to a trade in order to contribute to a liquid,
orderly market are defined as dealers. Further, the expression market-maker can be used for the “Specialist” from the NYSE and “Dealers” from the NASDAQ. The NYSE has seven specialist firms while the NASDAQ has nearly 300 market-makers. To each stock one or more market-makers can be assigned. They are responsible for the liquidity of the assigned stock. In most markets, market makers have to provide bid and ask quotes for the stocks they are responsible for. If more market-makers are assigned to a certain stock (e.g. dealers on NASDAQ), they are competing with each other by trying to provide the best bid-ask quotes [45].

7.4.1 Specialists (Market-Makers in NYSE)

A specialist is a type of market maker. He is a dealer representing a NYSE specialist firm - one of the main facilitators of trade on the exchange. The specialist holds an inventory of the stock, posts the bid and ask prices, manages limit orders and executes trades. Specialists are also responsible for managing large movements by trading out of their own inventory. If there is a large shift in demand on the buy or sell side, the specialist will step in and sell out of their inventory to meet the demand until the gap has been narrowed. There is usually one specialist per stock who stands ready to step in and buy or sell as many shares as needed to ensure a fair and orderly market in that security. Specialists working on the NYSE have four roles to fulfill in order to ensure a fair and orderly market [45].

7.4.1.1 Auctioneer

Because the NYSE is an auction market, bids and asks are competitively forwarded by investors. These bids and asks must be posted for the entire market, to enable maintenance of the best price. It is the job of the specialist to ensure that all bids and asks are reported in an accurate and timely manner, that all marketable trades are executed and that order is maintained on the floor. The specialist must also set the opening price for the stock every morning. This price can differ from the previous day's closing price based on after-hours news and events. The role of the specialist is to find the correct market price based on the supply and demand.
7.4.1.2 Agent

The specialist can also accept limit orders relayed by investors through brokers or electronic trading. It is the responsibility of the specialist to ensure the order is transacted appropriately on behalf of others, using the same fiduciary care as the brokers themselves once the price of the stock has reached the limit criteria.

7.4.1.3 Catalyst

Because the specialists are in direct contact with the bidders and sellers of particular securities, it is their responsibility to ensure that enough interest exists for a particular stock. This is carried out by specialists seeking out recently active investors in cases where the bids and asks can't be matched. This aspect of the specialist's job helps to induce trades that may not have happened if the specialist had not been there to bring buyers and sellers together.

7.4.1.4 Principal

In the instance where there's a demand-supply imbalance in a particular security, the market maker must make adjustments by purchasing and selling out of his or her own inventory to equalize the market. If the market is in a buying frenzy, the specialist will provide shares from his inventory until the price is stabilized. A specialist will also buy shares for his inventory in the event of a large sell off.

7.4.2 Broker-Dealers (Market-Makers in NASDAQ)

A broker-dealer firm is one that accepts the risk of holding a certain number of shares of a particular security in order to facilitate trading in that security. Each market maker competes for customer order flow by displaying buy and sell quotations for a guaranteed number of shares. Once an order is received, the market maker immediately sells from its own inventory or seeks an offsetting order. This process takes place in mere seconds. The NASDAQ is the prime example of broker-dealer market-makers. There are more than 500 member firms that act as NASDAQ market makers, keeping the financial markets running efficiently because they are willing to quote both bid and offer prices for an asset. Market makers working on the NASDAQ exchange are not actually at the exchange. They are large investment companies that buy and sell securities through an
electronic network. These market makers maintain inventories and buy and sell stocks from their inventories to individual customers and other dealers. Each market maker on the NASDAQ is required to give a two-sided quote, meaning they must state a firm bid price and a firm ask price that they are willing to honor. Each security on the NASDAQ generally has more than one market maker, with an average of 14 market makers for each stock; this provides liquidity and efficient trading. The market makers are openly competitive and facilitate competitive prices; as a result, individual investors generally will get the best price. As this competition is evident in the limited spreads between posted bids and asks, the market makers on the NASDAQ will in some instances act very much like the specialists on the NYSE.

7.4.3 Dealer Vs Auction Market

The fundamental difference between the NYSE and NASDAQ is in the way securities on the exchanges are transacted between buyers and sellers. The NASDAQ is a dealer’s market, wherein market participants are not buying from and selling to one another directly but through a dealer, which, in the case of the NASDAQ, is a market maker. The NYSE is an auction market, wherein individuals are typically buying and selling between one another and there is an auction occurring; that is, the highest bidding price will be matched with the lowest asking price. The definitions of the role of the market maker and that of the specialist are technically different; a market maker creates a market for a security, whereas a specialist merely facilitates it. However, the duty of both the market maker and specialist is to ensure smooth and orderly markets for clients. If there is nobody willing to buy or sell, the market makers of the NASDAQ and the specialists of the NYSE will try to see if they can find buyers and sellers and even buy and sell from their own inventories. The NASDAQ is typically known as a high-tech market, attracting many of the firms dealing with the internet or electronics. The companies on NYSE include many of the blue chip firms and industries that were around for some time, and its stocks are considered to be more stable and established.
7.4.4 Bid-Ask Spread

The stock market is a dynamic and interactive environment where investors submit their orders given the bid and ask prices (or quotes) from the market-maker. The market-maker in turn sets the quotes in response to the flow of orders. The job of the market-maker is to observe the order flow, the change of its portfolio, and its execution of orders and set quotes in order to maximize some long-term rewards that depend on its objectives (e.g. profit maximization and inventory risk minimization). In order for this to happen, the quotes have to straddle the “true price” of the security [45] and be positioned as close to it as possible. However, the “true price” is an elusive concept, difficult to determine or model. Therefore, the first decision for the market maker (either human or, artificial) is where to establish the initial spread. There are two ways to approach this decision. The first, hard way is to perform the actual valuation of the security being traded: for a stock, try to determine the value of the company using discounted cash flows, ratios, etc.; for a bond, find the present value of the promised payments, and so on. If there is no established market, or the market is very illiquid, then valuation may be the only approach [45].

7.4.5 Limit-Orders

In case where markets employ limit orders in some capacity, the two queues of the order book should be an accurate representation of the current supply (sell queue) and demand (buy queue) for the security. Presented with such supply-demand schedule, the market maker tries to determine the consensual value. In the simplest case, the dealer can observe the top of each book – the best (highest) buy and the best (lowest) sell – also known as the “inside market”. He then assumes that the market’s consensus about the price lies somewhere between these two numbers. Now, the market maker can use the top of each book as a reference point for positioning his initial quotes and then update his spread as the book evolves with new arrivals, transactions and cancellations.
7.4.6 Effects of Updating the Spread

Updating the spread is at the heart of market making. While the order book is informative about the consensus price of the security, it often fails to provide sufficient liquidity, thus creating demand for market makers. Demands of investors create inefficiencies because investors demand liquidity, thus driving a need for market makers. Market makers have risk aversion, which means that once they acquire positions, they have to off-load them. But risk aversion means that their actions are somewhat predictable. For example, if they off-load their positions gradually, they cause trends in prices. Trends in prices are exploited by technical traders, who analyze patterns in past prices and trade accordingly [31]. Thus, we see how the demand for liquidity can sustain a population of technical traders, even though the technical traders are not providing liquidity directly. Money flows from liquidity demanders to technical traders. This pattern does not mean the market is not pretty efficient; it just means that this approximate efficiency comes about only through a web of interactions among heterogeneous players, who are all part of an interconnected market ecology.

7.4.7 Approaches to Market Making Problem

The understanding of the price formation process in security markets has been one of the focal points of the market microstructure literature. There are two main approaches to the market-making problem, classified as given below:

- Inventory-based model
- Information-based model

In an inventory-based model, the market-maker sets the price to balance demand and supply in the market, where as, the second approach attempts to explain the price setting dynamics employing the role of information.

7.5 The Bombay Stock Exchange (BSE)

The BSE has evolved over the years into its present status as the premier Stock Exchange in India. Appendix A is a case study on the BSE. Though many other exchanges exist, BSE and the NSE account for the majority of the equity trading in India.
The 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. Although this has the advantage of giving the investors a better price, growth of the market has been hampered by a relatively high degree of volatility [77].

7.5.1 Persistence of Volatility in Indian Stock Markets

Various studies and analyses on the Indian Stock Markets show that being an emerging market, the volatility of the market is relatively high when compared to that of the other matured developed stock markets like NASDAQ and NYSE. The absence of market makers in Indian markets could be one of the main reasons for this volatility and hence merits further investigation.

7.5.2 Illiquid Stocks in Indian Stock Market

Further, there are a large number of shares in the Indian stock market that are not actively traded despite the fact that many of them have intrinsic value. To provide liquidity to the illiquid scrip, market makers are required who will continuously provide two way quotes [91].

7.5.3 The Market Making Status in BSE

Internationally, the market making concept is highly advanced and a highly specialized job, with select firms specializing in it. However, in the Indian context, there are no market makers in the organizational structure of BSE or NSE. Market making was much in use in BSE during the floor-based trading era, when jobbers used to play the role of market makers. However in this screen based trading era, they are absent. The Securities and Exchange Board of India (SEBI) has come out with specific guidelines for market makers in Small and Medium Enterprises (SME) exchanges only. It has made market making mandatory in respect of all scrips listed and traded on SME exchanges.

7.6 Artificial Stock Markets (ASM)

ASM are models of financial markets used to study and understand market dynamics. The key property is that in this environment, prices should emerge internally as a result of trading interactions of the market participants represented. ASM are composed of many
heterogeneous interacting adaptive traders [20,21], rich in emergent properties wherein prices emerge as a result of interaction among market participants.

### 7.6.1 Agent Based ASM

In Agent based ASM, traders and market participants are represented as agents. It is a bottom-up system approach to forecast and understand the behavior of non-linear systems. Various studies manage to explain emergent properties of ASM from the interaction between heterogeneous traders (agents) [8,63,64,65]. ASM models are capable of demonstrating the various characteristics of stock markets. The agent-based approach considers a population of intelligent adaptive agents and lets them interact in order to maximize their financial performance. Interaction between agents is a key feature of the agent-based systems: prices arise from simulating the interactions of autonomous entities with different profit-making strategies. The collective behavior of such groups of individuals is not determined by a single mechanism, but by the interaction of individual behaviors distributed across the group and it is only by the individual behaviors that the group behavior can emerge. This indeed is the mechanism prevailing in stock markets and hence the aptness of agent based models for analysis.

### 7.6.2 Market Making Strategies

There are two main approaches to the market-making problem [17]. One focuses on the uncertainties of an order flow and the inventory holding risk of a market-maker. In a typical inventory-based model, the market-maker sets the price to balance demand and supply in the market while actively controlling its inventory holdings [31]. The second approach attempts to explain the price setting dynamics employing the role of information [39]. In information-based models, the market maker faces traders with superior information. The market-maker makes inferences from the orders and sets the quotes. This informational disadvantage is reflected in the bid-ask spread. Inventory-based models focus on the role of order flow uncertainty and inventory risk in the determination of the bid-ask spread. The information-based approach suggests that the bid-ask spread could be a purely informational phenomenon irrespective of inventory risk.
7.6.3 An Analysis of Inventory Based Models

In a typical inventory-based model, the market-maker sets the price to balance demand and supply in the market while actively controlling its inventory holdings. It focuses on the uncertainties of an order flow and the inventory holding risk of a market-maker. Garman (1976) [34] describes a model in which there is a single, monopolistic, and risk neutral market maker who sets prices, receives all orders, and clears trades. The dealer’s objective is to maximize expected profit per unit time. Failure of the market-maker arises when it runs out of either inventory or cash. Arrivals of buy and sell orders are characterized by two independent Poisson processes whose arrival rates depend on the market-maker’s quotes. Essentially the collective activity of the traders is modeled as a stochastic flow of orders. Ho & Stoll [51] studies the optimal behavior of dealers who is faced with a stochastic demand and return risk of his own portfolio. As in [34], orders are represented by price-dependent stochastic processes. However, instead of maximizing expected profit, the dealer maximizes the expected utility of terminal wealth which depends on trading profit and returns to other components in its portfolio. Consequently dealer’s risks play a significant role in its price-setting strategy. One important implication of this model is that the spread can be decomposed into two components: a risk neutral spread that maximizes the expected profits for a set of given demand functions and a risk premium that depends on the transaction size and return variance of the stock. Ho & Stoll have studied the behavior of a single dealer followed by multiple-dealers. The price-dependent stochastic order flow mechanism is common in the above studies. All preceding studies only allow market orders traded in the market. The ABMI model, based on an order-driven market [31] illustrates how simple agent-based systems can be used for modeling and studying stock markets. There are a few types of investors and a market maker, all represented as agents. The role of the market maker is to adjust prices as a function of the order imbalance. The study shows in what sense the market mechanism matters: risk-averse behavior of the market maker, for example, introduces trends in prices. This is caused by the fact that if the market maker acquires a position he wants to get rid of it. Structure in price series creates opportunity for technical traders. In the model there is a point at which the market is efficient (i.e. everyone breaks even). The authors analyze under which conditions the market will converge to this point.
7.6.4 An Analysis of Information Based Models

In information-based models, the market-maker faces traders with superior information. The market-maker makes inferences from the orders and sets the quotes. This informational disadvantage is reflected in the bid-ask spread. Glosten & Milgrom (1985) [39] studies the market-making problem in a market with asymmetric information. In the Glosten-Milgrom model some traders have superior (insider) information and others do not. Traders consider their information and submit orders to the market sequentially. The specialist, which does not have any information advantage, sets his prices, conditioning on all his available information such that the expected profit on any trade is zero. Specifically, the specialist sets its prices to equal the conditional expectation of the stock value given past transactions. Its main finding is that in the presence of insiders, a positive bid-ask spread would exist even when the market-maker is risk-neutral and make zero expected profit. In Das (2003) [25] and Das (2005) [26] a nonparametric density estimation technique is proposed for maintaining a probability distribution over a range of expected true values. The market-maker uses these probability estimates to set bid and ask prices [26]. This model extends the Glosten and Milgrom (1985) information-based model, which was proposed to show the influence of informational asymmetry on the bid-ask spread in financial markets.

7.6.5 Summary

In modern financial markets, market-makers (or dealers) are agents who stand ready to buy and sell securities rendering markets more orderly and prices less volatile. In the two US markets of NYSE and NASDAQ, market-makers play a vital role in their structure in trading, where as, market-makers are absent in the Indian market organizational structure. The term market-maker can be used for the “Specialist” from the NYSE and “Dealers” from the NASDAQ. The difference between the NYSE and NASDAQ is in the way securities on the exchanges are transacted between buyers and sellers. The NASDAQ is a dealer’s market, wherein market participants are not buying from and selling to one another directly but through a dealer (market-maker). The NYSE is an auction market, wherein individuals are typically buying and selling between one another and there is an auction occurring. Market-maker quotes two prices – a “bid” (dealer’s purchase,
customer’s sale) and an “ask” (dealer’s sale, customer’s purchase). The ask is higher than the bid, and the difference between the two is called the spread. Updating the spread is at the heart of market making. There are two main approaches to the market-making problem, viz, Inventory-based model and Information-based model. Inventory-based models (as in ABMI) focus on the role of order flow uncertainty and inventory risk in the determination of the bid-ask spread, whereas, the information-based approach (EGM) suggests that the bid-ask spread could be a purely informational phenomenon irrespective of inventory risk.

7.7 A Market Maker for BSE

The rationale discussed above on the aspects of high volatility and illiquidity of scrip (with reasonable intrinsic value) in the BSE provides the basic motivation for this study. Data from the BSE is chosen for the purpose of analysis. An attempt is made to demonstrate that introduction of a suitable market maker model for the BSE would bring about stability and regulate the prevailing volatility. This could also herald the much needed liquidity in those illiquid stocks with intrinsic value. The Extended Glosten and Milgrom Model proposed by Das [25, 26] is an Information based Agent Based ASM model. The suitability of Extended Glosten and Milgrom (EGM) market maker model as the electronic market maker for the BSE is analysed further. The market maker in the EGM model quotes the bid and ask prices based on the orders placed by the pool of traders. It is shown that in the EGM model, the market maker’s quotes are comparable to the fundamental value of the stock and any sudden change in the fundamental value (in case of jumps) causes fluctuations in the quotes that are very quickly resolved, thereby bringing stability in the market.

7.7.1 Extended Glosten and Milgrom Model

Glosten and Milgrom analyze the market-maker’s decision problem with informed (insider) and uninformed (liquidity) traders [39]. The algorithm presented for market making explicitly computes the approximate solutions to the price setting equations that include the periodic probabilistic shocks to the underlying fundamental value. The impact of different parameters assumed for solving the equations is studied as a two regime behavior in which extreme heterogeneity of information following a jump to the
fundamental value characterized by high spreads and high volatility is quickly resolved to a state of homogeneity characterized by low spreads and low volatility. Glosten and Milgrom derive the market-maker's price setting equations under asymmetric information to be such that the bid quote is the expectation of the true value given that a sell order is received and the ask quote is the expectation of the true value given that a buy order is received. The theoretical model of Glosten and Milgrom is extended into a more realistic setting.

7.7.2 The Market Making Model

The market is a discrete time dealer market with only one stock. The market-maker sets bid and ask prices \( (P_b \text{ and } P_a \text{ respectively}) \) at which it is willing to buy or sell one unit of the stock at each time period. All transactions occur with the market-maker taking one side of the trade and a member of the trading crowd taking the other side [25]. The stock has an underlying fundamental value \( V_i \) at time period \( i \). All market makers are informed of \( V_0 \) at the beginning of a simulation, but do not receive any direct information about \( V \) after that. At time period \( i \), a single trader is selected from the trading crowd and allowed to place either a buy or sell order for one unit of the stock.

7.7.3 Types of Traders

There are two types of traders in the market, uninformed traders and informed traders. An uninformed trader will place a buy or sell order for one unit with equal probability, or no order with some probability if selected to trade. An informed trader who is selected to trade knows \( V_i \) and will place a buy order if \( V_i > P_a^i \), a sell order if \( V_i < P_b^i \) and no order if \( P_a^i \geq V_i \geq P_b^i \). In addition to perfectly informed traders, there are noisy informed traders. A noisy informed trader receives a signal of the true price \( W_i = V_i + \eta(0, \sigma_w) \) where \( \eta(0, \sigma_w) \) represents a sample from a normal distribution with mean 0 and variance \( \sigma_w \). The noisy informed trader believes this is the true value of the stock, and places a buy order if \( W_i > P_a^i \), a sell order if \( W_i < P_b^i \) and no order if \( P_b^i \leq W_i \leq P_a^i \). The true underlying value of the stock evolves according to a jump process. At time \( i + 1 \), with probability \( p \), a jump in the true value occurs. When a jump occurs, the value changes according to the equation \( V_{i+1} = V_i + \omega(0, \sigma) \) where \( \omega(0, \sigma) \) represents a sample from a normal distribution with mean 0 and variance \( \sigma \). Market-makers are informed of when a
jump has occurred, but not of the size or direction of the jump. This model of the evolution of the true value corresponds to the notion of the true value evolving as a result of occasional news items. The periods immediately following jumps are the periods in which informed traders can trade most profitably, because the information they have on the true value has not been disseminated to the market yet, and the market maker is not informed of changes in the true value and must estimate these through orders placed by the trading crowd. The market-maker will not update prices to the neighborhood of the new true value for some period of time immediately following a jump in the true value, and informed traders can exploit the information asymmetry.

7.7.4 The Market Making Algorithm

The market-maker attempts to track the true value over time by maintaining a probability distribution over possible true values and updating the distribution when it receives signals from the orders that traders place. The true value and the market-maker's prices together induce a probability distribution on the orders that arrive in the market. The market-maker must maintain an online probabilistic estimate of the true value. Glosten and Milgrom analyze the setting of bid and ask prices so that the market maker enforces a zero profit condition. Glosten and Milgrom suggest that the market maker should set $P_b = E[V|\text{Sell}]$ and $P_a = E[V|\text{Buy}]$. The market-making algorithm computes these expectations using the probability density function being estimated.

7.7.5 Bid and Ask Price Equations

Let $\alpha$ be the proportion of informed traders in the trading crowd, and let $\eta$ be the probability that an uninformed trader places a buy (or sell) order. Then the probability that an uninformed trader places no order is $1 - 2\eta$. The Equation for the bid price ($P_b$) is

$$P_b = \frac{1}{P_{\text{Sell}}} \sum_{V_i = V_{\text{min}}}^{V_i = P_b} \left[ \left( (1 - \alpha)\eta + \alpha \Pr(\bar{\eta}(0, \sigma_{\bar{\eta}}) > (P_b - V_i) ) \right) V_i \Pr(V = V_i) \right]$$

$$+ \frac{1}{P_{\text{Sell}}} \sum_{V_i = P_b + 1}^{V_i = V_{\text{max}}} \left[ \left( (1 - \alpha)\eta + \alpha \Pr(\bar{\eta}(0, \sigma_{\bar{\eta}}) > (V_i - P_b) ) \right) V_i \Pr(V = V_i) \right]$$

(7.1)

where $P_{\text{Sell}}$ is given as,

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The equation for the ask price ($P_a$) is,

$$P_a = \sum_{V_i=V_{\min}}^{V_i=V_{\max}} \left[ \alpha \Pr(\bar{\eta}(0, \sigma^2_W) > (P_a - V_i)) + (1 - \alpha) \eta \right] V_i \Pr(V = V_i) +$$

$$+ \sum_{V_i=V_{\min}}^{V_i=V_{\max}} \left[ \alpha \Pr(\bar{\eta}(0, \sigma^2_W) < (V_i - P_a)) + (1 - \alpha) \eta \right] V_i \Pr(V = V_i)$$

(7.2)

where $P_{Buy}$ is given as,

$$P_{Buy} = \sum_{V_i=V_{\min}}^{V_i=V_{\max}} \left[ \alpha \Pr(\bar{\eta}(0, \sigma^2_W) > (P_{Buy} - V_i)) + (1 - \alpha) \eta \right] V_i \Pr(V = V_i) +$$

$$+ \sum_{V_i=V_{\min}}^{V_i=V_{\max}} \left[ \alpha \Pr(\bar{\eta}(0, \sigma^2_W) < (V_i - P_{Buy})) + (1 - \alpha) \eta \right] V_i \Pr(V = V_i)$$

(7.3)

If the initial true value is $V_0$, then the agent constructs a vector going from $(V_0 - 4\sigma)$ to $(V_0 + 4\sigma)$ to contain the prior value probabilities. The probability that $V = (V_0 - 4\sigma + i)$ is given by the $i$th value in this vector. The vector is initialized by setting the $i$th value in the vector to

$$\int_{-4\sigma+i}^{-4\sigma+i+1} N(0, \sigma) \, dx$$

(7.5)

where $N$ is the normal density function in $x$ with specified mean and variance. The vector is maintained in a normalized state at all times so that the entire probability mass for $V$ lies within it.

### 7.7.6 Updating the Density Estimate

The market-maker receives probabilistic signals about the true value. With perfectly informed traders, each signal says that with a certain probability, the true value is lower (higher) than the bid (ask) price. With noisy informed traders, the signal differentiates between different possible true values depending on the market-maker’s bid and ask quotes. Each time that the market-maker receives a signal about the true value by receiving a market buy or sell order, it updates the posterior on the value of $V$ by scaling
the distributions based on the type of order. In the case of perfectly informed traders, the signal only specifies that the true value is higher or lower than some price, and not how much higher or lower. In that case, the update equations are as follows.

- If a market buy order is received, this is a signal that with probability \((1 - \alpha)\eta + \alpha, V > P_a\).

- Similarly, if a market sell order is received, the signal indicates that with probability \((1 - \alpha)\eta + \alpha, V < P_b\).

- For a buy order, all probabilities for \(V = V_i, V_i > P_a\) are multiplied by \([1 - (1 - \alpha)\eta + \alpha]\), while all the other discrete probabilities are multiplied by \([1 - \alpha - (1 - \alpha)\eta]\).

- Similarly, when a sell order is received, all probabilities for \(V = V_i, V_i < P_b\) are multiplied by \([1 - (1 - \alpha)\eta + \alpha]\), and all the remaining discrete probabilities are multiplied by \([1 - \alpha - (1 - \alpha)\eta]\) before renormalizing.

### 7.7.7 Experimental Evaluation

All simulations take place in a market populated by noisy informed traders and uninformed traders. The noisy informed traders receive a noisy signal of the true value of the stock with the noise term being drawn from a Gaussian distribution with mean 0 and standard deviation 1 INR. The standard deviation of the jump process for the stock is 10 INR, and the probability of a jump occurring at any time step is 0.005. The probability of an uninformed buy or sell order is 0.5. The market-maker is informed of when a jump occurs, but not of the size or direction of the jump. Figure 7.1: shows the market maker tracking of the fundamental value over a course of 10000 rounds.

### 7.7.8 Prices near a Jump

Figure 7.2 shows the asymmetry of information immediately following a jump in the fundamental value. The market maker is quickly able to resolve this asymmetry of information. This period is when the spreads are high because the market maker is uncertain about the new fundamental value.
Figure 7.1: The market maker tracking the fundamental value.

Figure 7.2: Asymmetry of information immediately following a jump in the fundamental value.

Figure 7.3: Increased spreads immediately when the jump has occurred.
The increased spreads immediately after the jump has occurred, can be seen in Figure 7.3. Figure 7.4 demonstrates that the informational asymmetry gets resolved very quickly (within thirty trades) independent of the standard deviation of the jump process.

![Graph showing average spread for time periods away from the jump](image)

**Figure 7.4**: Average spread for time periods away from the jump shown for different standard deviations of the jump process

### 7.7.9 Market Maker’s Profit

Profit can be made by increasing the spread by pushing the bid and ask prices apart after the zero-profit bid and ask prices have been computed using the density estimate obtained by the market-making algorithm. With lower spreads, most of the market-maker's profits come from the noise factor of the informed traders, whereas with a higher spread, most of the market-maker's profits come from the trades of uninformed traders. However, increasing the spread beyond a point is counterproductive if there are enough noisy informed traders in the markets, because then the market-maker's prices are far enough away from the true value that even the noise factor cannot influence the informed traders to make trades. The graph in Figure 7.5 shows the different shaped curves for different values of $\alpha$ (ratio of informed to uninformed traders). When 50% of traders are
noisy informed the average profit increases proportionally with the increase in spread.

![Figure 7.5: Average spread for increase in different values of α](image)

### 7.8 Implementation of EGM for BSE

The system diagram for the implementation is given in Figure 7.6.

![Figure 7.6: Implementation System Diagram](image)

#### 7.8.1 Functions of the Market Maker

- The probability is evaluated for a jump in the fundamental value, and the jump is carried out if it is the case.
- An investor (type) is selected randomly from the pool to place an order.
- A Buy; Sell, or No order is sent by the selected trader to the market maker.
• The market maker processes the order and carries out the transaction if it is the case.
• The market maker updates his probability density estimate of possible fundamental values.
• The market maker updates the bid and ask prices ($P_b$ and $P_a$).

### 7.8.2 Demonstration of the EGM for BSE

This section contains the demonstration of the Extended Glosten and Milgrom model that was explained above for the BSE. The market and price-setting models outlined above is utilized to demonstrate that the inclusion of a market maker will considerably stabilize and reduce the volatility in the market. BSE SENSEX and five stocks each representing one sector of the market are considered from the Indian stock market.

### 7.8.3 Graham’s Intrinsic Value (GIV)

Graham [43] suggested a straightforward practical tool for evaluating a stock’s intrinsic value. His model represents a valuation approach that focuses on the key market-related and company-specific variables. The Graham formula proposes to calculate a company’s intrinsic value $V$ as:

$$ V = \frac{(\text{EPS} \times (8.5 + 2g) \times 4.4)}{Y} \quad (7.6) $$

Where,

<table>
<thead>
<tr>
<th>$V$</th>
<th>Intrinsic Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS</td>
<td>The company’s last 12-month Earnings Per Share</td>
</tr>
<tr>
<td>8.5</td>
<td>The constant represents the appropriate P-E ratio for a no-growth company</td>
</tr>
<tr>
<td>$g$</td>
<td>The company’s earnings growth estimate</td>
</tr>
<tr>
<td>4.4</td>
<td>The average yield of high-grade corporate bonds (in the year of its introduction)</td>
</tr>
<tr>
<td>$Y$</td>
<td>The risk free interest rate</td>
</tr>
</tbody>
</table>

To apply this approach to a buy-sell decision, each company’s Relative Graham Value (RGV) can be determined by dividing the stock’s intrinsic value $V$ by its current price $P$.

$$ \text{RGV} = \frac{V}{P} \quad (7.7) $$

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An RGV of less than one indicates an overvalued stock and not to be bought, while an RGV of greater than one indicates an undervalued stock and to be bought.

### 7.8.4 Implementation of EGM

The entity GIV, used as a factor for deciding whether to buy or sell a stock, is employed as the fundamental value of a stock for our market simulation. The GIV of the selected stocks are calculated from their respective EPS (Earnings per Share) for the years from 2005-2010 [132]. Every time the GIV changes, it is considered that a jump has occurred in the fundamental value of a stock. Hence, every GIV is used for 248 rounds (average number of working days in a year). The stocks that are considered are shown in Table 7.1 and their GIV data is given at Table 7.2.

**Table 7.1: Stocks/Index considered for EGM Model for BSE.**

<table>
<thead>
<tr>
<th>Stock/Index</th>
<th>Entity Represented</th>
</tr>
</thead>
<tbody>
<tr>
<td>SENSEX(BSE)</td>
<td>Indian market</td>
</tr>
<tr>
<td>SBI</td>
<td>Banking Industry</td>
</tr>
<tr>
<td>Infosys</td>
<td>IT industry</td>
</tr>
<tr>
<td>HDFC</td>
<td>Housing and finance industry</td>
</tr>
<tr>
<td>NTPC</td>
<td>Energy industry</td>
</tr>
<tr>
<td>L&amp;T</td>
<td>Infrastructure industry</td>
</tr>
</tbody>
</table>

**Table 7.2: GIV Data for the different stocks considered**

<table>
<thead>
<tr>
<th>Period</th>
<th>SENSEX</th>
<th>HDFC</th>
<th>NTPC</th>
<th>INFOSYS</th>
<th>L&amp;T</th>
<th>SBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>2389.037</td>
<td>222.948</td>
<td>26.444</td>
<td>398.86</td>
<td>263.12</td>
<td>368.236</td>
</tr>
<tr>
<td>2007</td>
<td>3245.445</td>
<td>271.8685</td>
<td>35.95018</td>
<td>254.0532</td>
<td>196.6924</td>
<td>360.0101</td>
</tr>
<tr>
<td>2008</td>
<td>3592.032</td>
<td>258.8107</td>
<td>38.09985</td>
<td>339.1297</td>
<td>314.3467</td>
<td>466.6836</td>
</tr>
<tr>
<td>2009</td>
<td>3395.043</td>
<td>314.0419</td>
<td>36.03594</td>
<td>489.7737</td>
<td>171.8643</td>
<td>646.4859</td>
</tr>
<tr>
<td>2010</td>
<td>3276.955</td>
<td>421.3191</td>
<td>39.80727</td>
<td>384.2103</td>
<td>207.0185</td>
<td>569.8044</td>
</tr>
</tbody>
</table>

### 7.8.5 Results

The results are shown in Figures 7.7 to 7.18. For the purpose of illustration, the market maker’s quote is considered as the average of his bid and ask i.e. \( (P_a + P_b) / 2 \). This value generated from the EGM model, market/index value and the GIV of the stock are plotted in the graph. It can be observed that the market maker’s quote near faithfully tracks the GIV except during the periods of heterogeneous information. The variance of the index
and variance of the market maker’s quotes with the GIV is also illustrated in the ibid
graphs. Obvious observations are that the market maker quotes prices that are closer to
the Graham’s Intrinsic Value of the stocks as against the prevailing market values.

7.9 Future Extensions

The EGM model that is shown in this document can be extended further by adding
more layers of complexity to the price-setting mechanism by the market maker. For
instance, the informed investors can be provided with initial wealth and thereby include
their own risk aversion factors into consideration while placing market orders. Further, as
suggested by Das[26], inventory control can be incorporated into the architecture of the
market-making algorithm by using it as an adjustment parameter, applied after bid and
ask prices have been determined, by raising or lowering the bid and ask prices by a linear
function of the inventory holdings of the market-maker.

7.10 Summary

Emerging stock markets are generally observed to be volatile in nature and Indian
markets are no exception. Further, a number of stocks in the Indian stock market remain
illiquid, despite possessing reasonably good intrinsic values. In the developed countries
of US and Europe, market makers/ specialists play a vital role in the functioning of stock
markets. They are responsible for a good and orderly market, whereas, the market makers
are absent in the Indian markets. In this chapter it is illustrated that introduction of market
makers in the Indian markets can bring about regulation of volatility. There are two main
approaches to the market-making problem: one focuses on the uncertainties of an order
flow and the inventory holding risk of a market-maker, and the second employs role of
information wherein the market-maker makes inferences from the orders and sets the
quotes. This informational disadvantage is reflected in the bid-ask spread.

In this analysis, information based strategy based on the Extended Glosten and
Milgrom Model proposed by Das is adopted. The agent based ASM is implemented
employing data from the BSE. Graham’s Intrinsic Value is considered as the fundamental
value of an index/stock, and using the strategy in EGM, the market maker’s bid-ask
prices are evaluated. The results show that the quote of the market maker closely reflects
the fundamental/intrinsic value of stocks. The far reduced variance of the market maker’s quote from the fundamental value, vis-a-vis that of the market value of the stock clearly demonstrate that this strategy can indeed regulate volatility in the BSE. Also, by giving two way quotes, the much needed liquidity of stocks can also be expected.

Figure 7.7: Market Maker’s quotes for GIV Vs SENSEX

Figure 7.8: Market Maker’s quotes for GIV Vs Market Price of SBI

Figure 7.9: Market Maker’s quotes for GIV Vs NTPC Market Price
Figure 7.10: Variance of SENSEX Vs Variation of Market Maker Quotes against GIV

Figure 7.11: Variance of SBI Market Price Vs Variation of Market Maker Quotes against GIV

Figure 7.12: Variance of NTPC Market Price Vs Variation of Market Maker Quotes against GIV
Figure 7.13: Market Maker’s quotes for GIV Vs L&T Market Price

Figure 7.14: Market Maker’s quotes for GIV Vs Infosys Market Price

Figure 7.15: Market Maker’s quotes for GIV Vs HDFC Market Price
Figure 7.16: Variance of L&T Market Price Vs Variation of Market Maker Quotes against GIV

Figure 7.17: Variance of Infosys Market Price Vs Variation of Market Maker Quotes against GIV

Figure 7.18: Variance of HDFC Market Price Vs Variation of Market Maker Quotes against GIV