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Agent Based Model for Market Making in Emerging Stock Markets

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Abstract

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. In order to make markets more efficient and an attractive venue for international investors, regulators are required to adopt a suitable market making design. For the purpose of the study on emerging stock markets, the Indian stock market data is analyzed in this paper. 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. 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 be an obvious reason for the prevailing high volatility and this issue is investigated in this paper. 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. This paper demonstrates the suitability of Extended Glosten and Milgrom (EGM) market maker model as the electronic market maker for the Bombay Stock Exchange (BSE) of India. The market maker in the EGM model sets the bid-ask prices based on the orders placed by the traders. It is shown that in the EGM model, the market maker's quotes reflect the intrinsic value of the stock and any 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 results of the experiments done on the real data from BSE show that, this model can be used as the market maker in the context of any emerging market. This would induce more stability and reduce the volatility, thereby making the market safe for genuine investors.

Keywords: Market Makers, Agent Based Models, Extended Glosten and Milgrom Model, Graham's Intrinsic Value

1. INTRODUCTION

1.1 Trading in Stock Exchanges

Evidence shows that the main problem the emerging stock markets face is capital supply shortage, volatility and lack of liquidity[1]. In order to make markets more efficient and an attractive venue for international investors, regulators are required to adopt a suitable market making design. 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. 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 Bombay Stock Exchange (BSE) and the National Stock Exchange (NSE) is an order driven market with fully automated screen based trading system.

1.2 The Bombay Stock Exchange (BSE)

The BSE is located on Dalal Street, Mumbai and it has evolved over the years into its present status as the premier Stock Exchange in India. The equity market capitalization of the companies listed on the BSE was US$1.63 trillion at the close of the last decade, making it the 4th largest stock exchange in Asia and the 8th largest in the world. Though many other exchanges exist, BSE and the NSE account for the majority of the equity trading in India.

The BSE trading system is order driven, wherein the buyers and sellers transact directly with each other. Although this is a good model, the market growth has been stymied by a relatively high degree of volatility[2].

1.3 Persistence of Volatility in Indian Stock Market

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. Figure.1 compares the index volatility of the Indian stock markets namely, BSE (SENSEX) and NSE (NIFTY) with NASDAQ for the years for the last decade. The X-axis represents the trading days and the Y-axis represents the variance of the indices on a 30-day window. It can be seen 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[3].

The absence of market makers in Indian markets could be one of the main reasons for this volatility and hence merits further investigation.

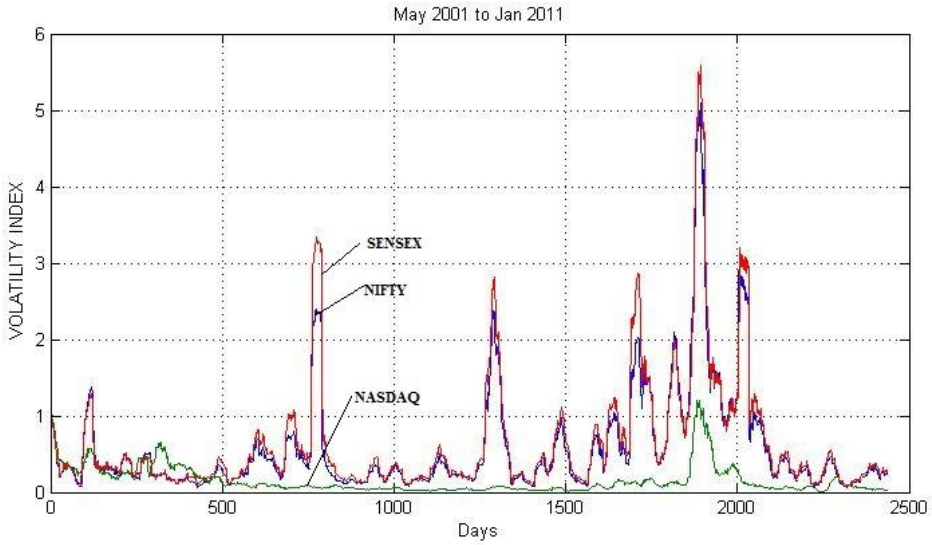

Figure.1. Volatility of the Indian Stock Markets Versus NASDAQ.

1.4 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[4].

1.5 Role of Market Makers/Specialists in a Stock Market

Market Makers are financial traders responsible for a good, orderly market [5], they make money by buying low and selling high. They accept the risk of holding a certain number of shares of a particular security in order to facilitate trading in that security. Each market maker displays buy and sell quotations for a guaranteed number of shares. The NASDAQ is the prime example of an operation of market makers wherein there are more than 500 member firms acting as market makers. A *specialist* is a type of market maker. The NYSE has 7 specialist firms who act as market makers. The specialist holds inventories of the stock, posts the bid and asks prices, manages limit orders and executes trades. Specialists are also responsible for managing large movements by trading out of their own inventory. The specialist will intervene in case of large volatility of stock prices. There is usually one specialist per stock.

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. As of now, the Securities and Exchange Board of India (SEBI) has specific guidelines for market makers in Small and Medium Enterprises (SME) exchanges only, making it mandatory in respect of all scrips listed and traded on SME exchanges.

1.6 Objective of the Study

The rationale discussed above on the aspects of high volatility and illiquidity of scrip (with reasonable intrinsic value) in the Indian stock market 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 in the emerging markets would bring about stability and regulate the prevailing volatility. This could also herald the much needed liquidity in those illiquid stocks with intrinsic value.

2. AGENT BASED MODELING

2.1 Agent Based Artificial Stock Markets (ASM)

Market dynamics can be studied employing Artificial Stock Market (ASM) models. As a result of trading interactions of the market participants, the prices emerge internally[6]. Agent based ASM adopts a bottom-up systems approach showing emergent properties from the interaction between heterogeneous traders[7-13]. ASM models are capable of depicting the various characteristics of stock markets. The agent-based approach considers a population of intelligent adaptive agents and lets them maximize their financial performance - prices arise as a consequence of this interaction. The Extended Glosten and Milgrom Model proposed by Das[14,15] is an Information based Agent Based ASM model. The market making strategy proposed for the BSE is based on this EGM model.

2.2 Market Making Strategies

The market-making problem can be handled in two different ways[16], viz, on the uncertainties of an order flow and the inventory holding risk of a market-maker. In an inventory-based model, the market-maker sets the price to balance demand and supply in the market while actively controlling its inventory holdings[17]. The 2nd approach employs the role of information[18], wherein, the market maker responds to traders with superior information. The market-maker sets his quotes based on the orders placed, and this is in fact seen in the bid-ask spread[18]. Das[14,15] presents an algorithm for explicitly computing approximate solutions to the expected-value equations for setting prices in an extension of the Glosten & Milgrom model. The algorithm proposed by Das has been used to evaluate the performance of the EGM model employing the real stock market data of BSE.

3. EXTENDED GLOSTEN AND MILGROM MODEL

The market-maker's decision problem is depicted within the informed (insider) and uninformed (liquidity) traders[18]. The algorithm presented for market making computes the approximate solutions to the price setting equations. The market-maker's price setting equations are derived under asymmetric information 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.

3.1 The Market Model and Market-Making Algorithm

The market is modeled with only one stock with a discrete characteristic. The market-maker sets bid and ask prices (P_b and P_a respectively) and transactions occur with the traders taking the other side[14]. 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. At time period *i*, a single trader places a buy/sell order.

3.2 Types of Traders

There are 2 of traders in the market, viz, uninformed and informed traders. If selected to trade, an uninformed trader will place a buy/sell order with equal probability, or no order with some probability. An informed trader who is selected to trade knows V_i and will place a buy order if the fundamental value is greater than the ask price, and a sell order if lower than the bid price and no order otherwise.

A noisy informed trader receives a signal of the true price $W_i = V_i +$ ή$(0,\sigma_w)$ where ή$(0,\sigma_w)$ represents a sample from a normal distribution with mean 0 and variance σ_w. The noisy informed trader believes this is the true value of the stock, and places a buy order if the perceived true price is greater than the ask price and a sell order if lower than the bid price and no order otherwise. The true underlying value of the stock evolves - at time $i + 1$, a jump in the true value occurs with probability p. When a jump occurs, the value changes according to the equation $V_{i+1} = V_i +$ ώ$(0,\sigma)$ where ώ$(0,\sigma)$ represents a sample from a normal distribution with mean 0 and variance σ. The market-makers are informed of a jump, however, neither the size nor the direction is known. The informed traders make most profit at the periods immediately following jumps, because the information they have on the true value is not known to the market yet, and the market maker must estimate these through the orders placed on them. It is during this juncture that the informed traders exploit the information asymmetry since the market-maker will not be updating its prices to the new true value for some period of time immediately following a jump.

3.4 The Market-Making Algorithm

The market-maker maintains a probability distribution over possible true values and updates the distribution when it receives signals from the orders that traders place ie the market-maker maintains a probabilistic estimate of the true value. Glosten and Milgrom suggest that the market maker should set the bid price equal to E [V|Sell] and ask price to E [V|Buy]. In fact, the market-making algorithm computes these expectations.

3.5 Bid and Ask Price Equations

Let α be the proportion of informed traders, and let η be the probability that an uninformed trader places a buy (or sell) order. Then the probability that an uninformed trader places no order is 1-2η.

The Equation for the bid price (P_b) is

$$P_b = \frac{1}{P_{sell}} \sum_{V_i=V_{min}}^{V_{i=P_b}} \left[\left((1-\alpha)\eta + \alpha \Pr\left(\tilde{\eta}(0,\sigma_W^2) > (P_b - V_i)\right)\right) V_i \Pr\left(V = V_i\right)\right] + \frac{1}{P_{sell}} \sum_{V_i=P_b+1}^{V_{i=V_{max}}} \left[\left((1-\alpha)\eta + \alpha \Pr\left(\tilde{\eta}(0,\sigma_W^2) > (V_i - P_b)\right)\right) V_i \Pr\left(V = V_i\right)\right]$$

where P_{Sell} is given as,

$$P_{sell} = \sum_{V_i=V_{min}}^{V_i=P_b-1} \left[\alpha \Pr\left(\tilde{\eta}(0,\sigma_W^2) < (P_b - V_i)\right) + (1+\alpha)\eta\right] \Pr(V = V_i) + \sum_{V_i=P_b}^{V_i=V_{max}} \left[\alpha \Pr\left(\tilde{\eta}(0,\sigma_W^2) > (V_i - P_b)\right) + (1+\alpha)\eta\right] \Pr(V = V_i) \quad (1)$$

The equation for the ask price (P_a) is,

$$P_a = \frac{1}{P_{Buy}} \sum_{V_i=V_{min}}^{V_{i=P_a}} \left[\left((1-\alpha)\eta + \alpha \Pr\left(\tilde{\eta}(0,\sigma_W^2) > (P_a - V_i)\right)\right) V_i \Pr\left(V = V_i\right)\right] + \frac{1}{P_{Buy}} \sum_{V_i=P_a+1}^{V_{i=V_{max}}} \left[\left((1-\alpha)\eta + \alpha \Pr\left(\tilde{\eta}(0,\sigma_W^2) < (V_i - P_a)\right)\right) V_i \Pr\left(V = V_i\right)\right] \quad \ldots\ldots \quad (2)$$

where P_{Buy} is given as,

$$P_{Buy} = \sum_{V_i=V_{min}}^{V_{i=P_a}} \left[\alpha \Pr\left(\tilde{\eta}(0,\sigma_W^2) > (P_a - V_i)\right) + (1-\alpha)\eta\right] V_i \Pr(V = V_i) + \left[\alpha \Pr\left(\tilde{\eta}(0,\sigma_W^2) > (V_i - P_a)\right) + (1-\alpha)\eta\right] V_i \Pr\left(V = V_i\right) \quad \ldots\ldots \quad (3)$$

The prior value probabilities are maintained in a vector going from (V_0 - 4σ) to (V_0 + 4σ -1)

3.6 Updating the Density Estimate

The market-maker records the signals about the true value:

- Perfectly informed traders: the true value is lower (higher) than the bid (ask) price.
- Noisy informed traders: different possible true values depending on the market-maker's bid and ask quotes.

The market-maker updates the posterior on the value of V. 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.

- For a market buy order - probability is $(1 - \alpha)\eta + \alpha$, $V > P_a$.
- For a market sell order - probability is $(1 - \alpha)\eta + \alpha$, $V < P_b$.
- For a buy order, all probabilities for $V = V_i$, $V_i > P_a$ are multiplied by $[(1 - \alpha)\eta + \alpha]$, and 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 $[(1 - \alpha)\eta + \alpha]$, and all the remaining discrete probabilities are multiplied by

$$[1 - \alpha - (1 - \alpha)\eta]. \quad (4)$$

4. EXPERIMENTAL EVALUATION

4.1 Experiment Framework

The simulation is done with the market populated by noisy informed traders and uninformed traders. The noisy informed traders receive a noisy signal with the noise value being drawn from a Normal distribution with mean 0 and standard deviation 1 INR. The standard deviation is 10 INR, with the jump probability of 0.005. The probability of an uninformed buy or sell order is 0.5. Figure.2 depicts a course of 10000 rounds.

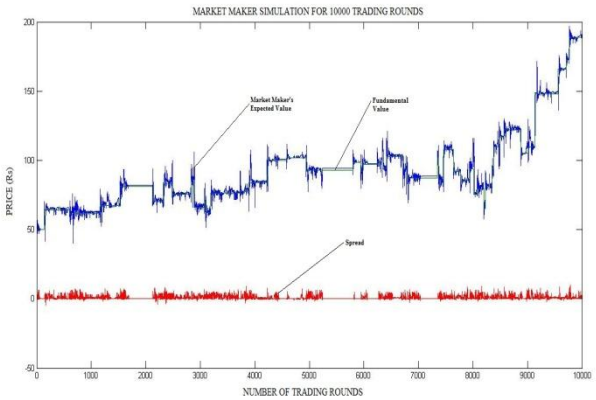

Figure.2. The market maker tracking the fundamental value.

4.2 Prices near a Jump

The information asymmetry immediately following a jump can be seen in Figure. 3. It can be seen that this asymmetry of information is overcome quickly by the market maker. The duration while the spread is high corresponds to that of the uncertainty prevailing with the market maker.

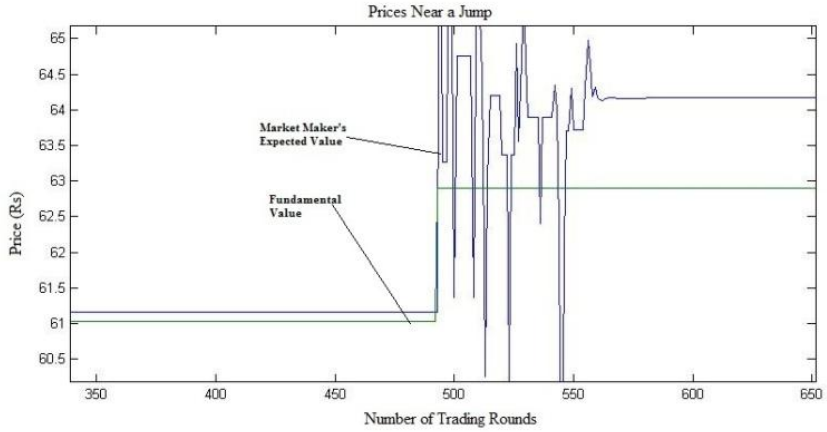

Figure.3. Asymmetry of information immediately following a jump in the fundamental value

5. IMPLEMENTATION OF EGM

5.1 Functions of the Market Maker

- A jump is carried out depending on the probability of occurrence.
- An order is placed with a randomly selected investor.
- The order is sent to the market maker.
- The transaction is implemented.
- The probability density estimate is updated.
- The bid and ask prices are updated.

5.2 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 are 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.

5.3 Graham's Intrinsic Value (GIV)

Graham[19] suggested a formula for evaluating a stock's intrinsic value: the valuation focuses on important market and company attributes. The Graham formula for a company's intrinsic value V is:

$$V = (EPS * (8.5 + 2g) * 4.4) / Y \quad (5)$$

Where,

V	Intrinsic Value
EPS	The company's last 12-month Earnings Per Share
8.5	Appropriate P-E ratio for a no-growth company
g	The company's earnings growth estimate
4.4	The average yield of high-grade corporate bonds (in the year of its introduction)
Y	The risk free interest rate

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 ie RGV = V:-P. An RGV < 1.0 could be an overvalued stock and an undervalued stock would have RGV > 1.0.

5.6 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[20]. 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).

5.7 Results

The results are shown in Figures. 4 to 15. 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. The stocks that are considered are shown in Table 1:

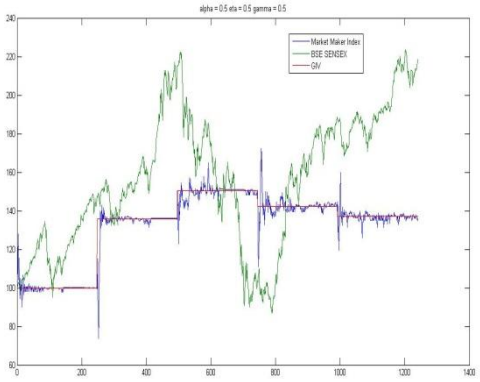

Figure 4: Market Maker's quotes for GIV versus SENSEX

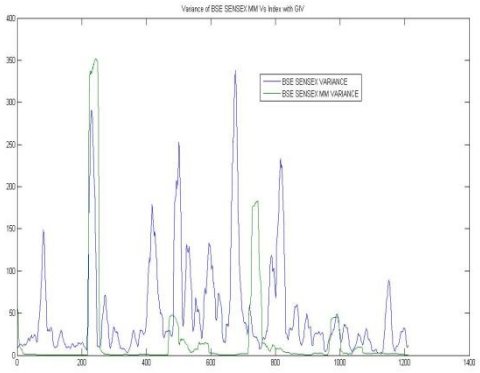

Figure 5: Variance of SENSEX versus Variation of Market Maker Quotes against GIV Market Maker Quotes against GIV

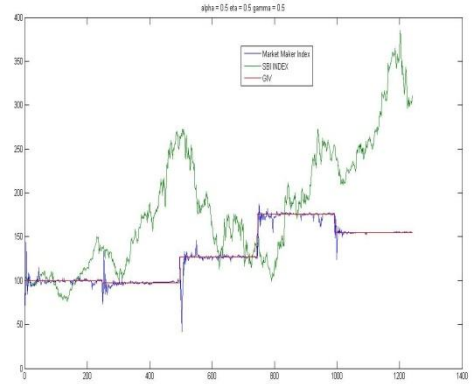

Figure 6: Market Maker's quotes for GIV versus Market Price of SBI

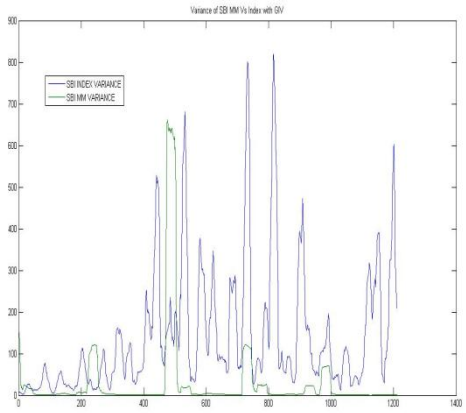

Figure 7: Variance of SBI Market Price versus Variation of Market Maker Quotes against GIV

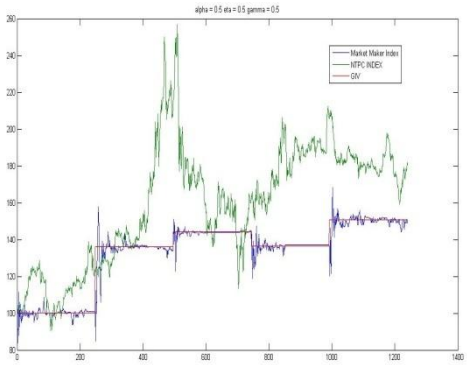

Figure 8: Market Maker's quotes for GIV versus NTPC Market Price

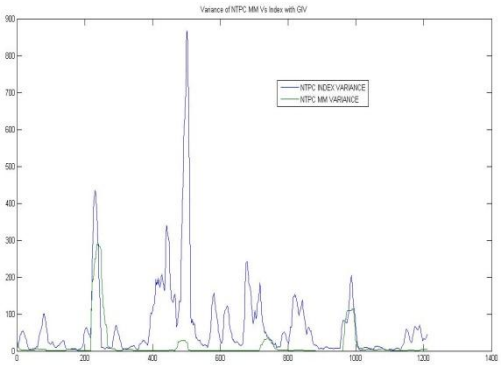

Figure 9: Variance of NTPC Market Price versus Variation of Market Maker Quotes against GIV

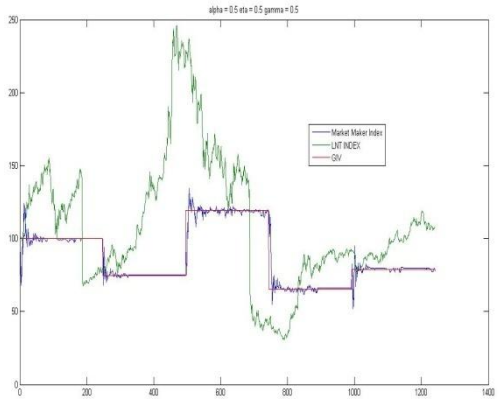

Figure 10: Market Maker's quotes for GIV versus L&T Market Price

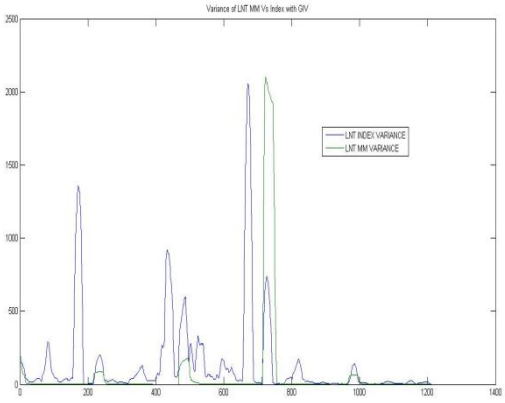

Figure 11: Variance of L&T Market Price versus Variation of Market Maker Quotes against GIV

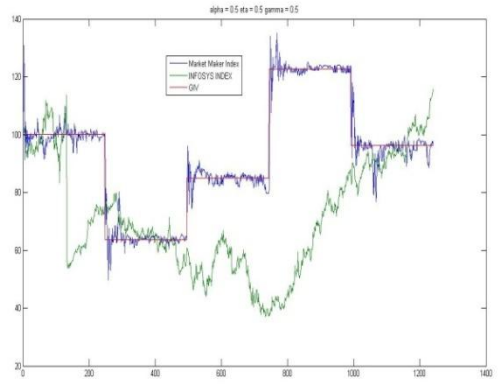

Figure 12: Market Maker's quotes for GIV versus Infosys Market Price

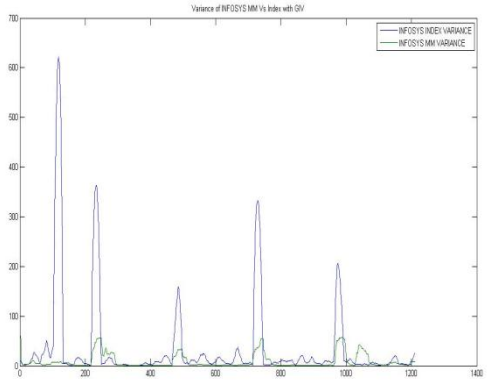

Figure 13: Variance of Infosys Market Price versus Variation of Market Maker Quotes against GIV

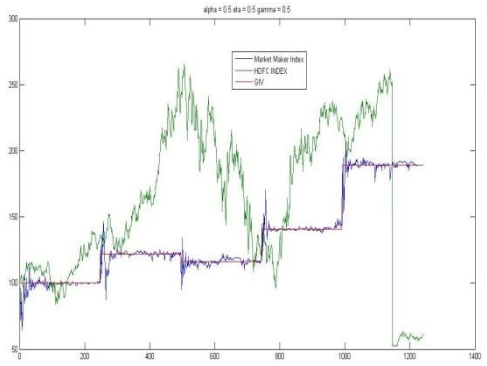

Figure 14: Market Maker's quotes for GIV versus HDFC Market Price

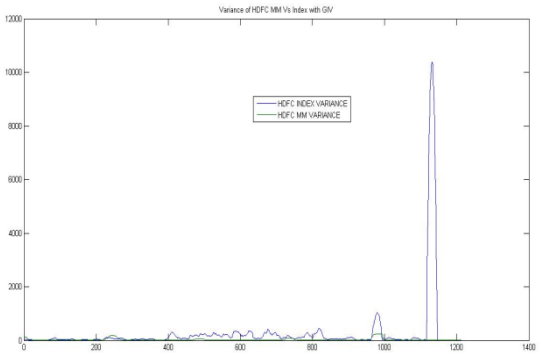

Figure 15: Variance of HDFC Market Price versus Variation of Market Maker Quotes against GIV

TABLE 1: Stocks/Index considered for EGM Model for BSE.

Stock/Index	Entity Represented
SENSEX(BSE)	Indian market
SBI	Banking Industry
Infosys	IT industry
HDFC	Housing and finance industry
NTPC	Energy industry
L&T	Infrastructure industry.

6. FUTURE EXTENSIONS

The EGM model that is shown in this document can be extended further. Complexities can be added to the price-setting mechanism by the market maker. Initial wealth can be factored for the informed investors with their own risk aversion factors. Further, as suggested by Das[15], inventory control can be incorporated into the market-making algorithm applied after bid and ask prices have been determined.

7. CONCLUSION

Emerging stock markets are generally observed to be volatile in nature and Indian markets are no exception. For the purpose of the study on emerging stock markets, the Indian stock market data is analysed in this paper. 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 have an important 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.

We illustrate that introduction of market makers in the Indian markets can bring about regulation of volatility. Focussing on the uncertainties of an order flow and the inventory holding risk of a market-maker, the market-maker makes inferences from the orders and sets the quotes leading to the bid-ask spread. This paper analyses the information based strategy proposed by Das and is based on the Extended Glosten and Milgrom Model (EGM). 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 set. The results show that the quote of the market maker follows 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 demonstrates that this strategy can indeed regulate volatility in such markets. Also, by giving two way quotes, the much needed liquidity of stocks can also be anticipated.

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