CHAPTER 2

DYNAMICS OF STOCK MARKETS

2.1 Introduction

Stock markets are complex systems; hence models are needed to study their dynamics. In order to understand the internals of ASM models, insight in the structure and workings of real stock markets is required. Market microstructure literature studies the institutional structure behind price formation in markets, analyzing the process by which investors’ demands are translated into transactions and prices [45]. Studying behavior of market participants is equally important because of its potential impact on asset prices. Agent-based simulation, as a methodology often used in studies of complex systems, can bridge the gap between the micro level of individual investor behavior and the macro level of aggregate market phenomena. Since agent-based simulation constitutes a bottom-up approach, a realistic description of the behavior of market participants and also their behavior should be studied first. For that purpose, this chapter elaborates the organization and functioning of stock markets, followed by a study on behavioral finance and psychological literature with an aim to describe how individual investors behave in the markets. An overview of Indian securities market with a detailed exposition on the BSE is given as a case study in Appendix A.

2.2 Securities Market

Transfer of resources from those with idle resources to others who have a pressing need for them is perhaps most efficiently achieved through the securities markets. Securities include shares, bonds, scrips, stocks or other marketable securities like derivatives etc. The securities market has essentially three categories of participants, viz, issuer of securities, the investors in the securities and the intermediaries. The issuers are the borrowers who issue securities to raise funds and the intermediaries are the agents who match the needs of users and suppliers of funds for a commission. The process of mobilization of resources is carried out under the
supervision and overview of the regulators. The regulators develop fair market practices and regulate the conduct of issuers of securities and the intermediaries. They are also in charge of protecting the interests of investors.

2.3 Market Segments

The securities market has two interdependent and inseparable segments, the new issues (primary) market and the stock (secondary) market. The primary market provides the channel for creation and sale of new securities, while the secondary market deals in securities previously issued. The securities issued in the primary market are issued by public limited companies or by government agencies. The resources of this kind of market are mobilized either through the public issue or through private placement route. There are two major types of issuers of securities, the corporate entities who issue mainly debt and equity instruments and the government who issue debt securities (dated securities and treasury bills). The secondary market enables participants who hold securities to adjust their holdings in response to changes in their assessment of risks and returns. Once the new securities are issued in the primary market they are traded in the stock (secondary) market. The secondary market operates through two media, namely, the Over-The-Counter (OTC) market and the Exchange-Traded market. OTC markets are informal markets where trades are negotiated. Most of the trades in the government securities are in the OTC market. All the spot trades where securities are traded for immediate delivery and payment take place in the OTC market. The other option is to trade through stock exchanges. All the trades taking place over a trading cycle (day=T) are settled together after a certain time (T+2 day). The trades executed are cleared by a clearing corporation, who acts as a counterparty and guarantees settlement. A variant of the secondary market is the forward market, where securities are traded for future delivery and payment. A variant of the forward market is Futures and Options market.

2.4 Market Microstructure

Market microstructure investigates trading and the organization of markets for trading in instruments [45]. A market is a place where traders gather to trade
instruments. That place may be a physical trading floor (e.g. NYSE), or it may be an electronic trading system (NASDAQ, BSE). Exchanges therefore provide forums where traders meet to arrange trades. In few markets, dealers and brokers arrange trades OTC. Price dynamics is the process by which prices change as a reaction to changes in the state of the market. Market prices are directly determined by the price formation mechanism that applies on a specific market. Prices are formed basically as a result of executing orders. Prices are indirectly influenced by several other factors that trigger orders, such as economy, news, financial situation of equity issuers, personal opinions (Figure 2.1) [88].

While it is easy to understand the trading actions that participants take, it is difficult to unravel as to what governs these actions. The difficulty of understanding market dynamics arises from the presence of such hardly observable aspects for e.g.: the price formation mechanism (related to the organization of the market) and the decision-making mechanism (related to the behavior of market participants) of the traders [8,45]. This is denoted as cloudy areas in Figure 2.2. The literature on market microstructure investigates trading and the organization (structure) of markets [78]. The structure of a market is defined by trading rules and trading systems and determines who the participants are and when and how trading takes place, and further what traders can know and do in a market. The structure provides the framework within which the trading takes place. Microstructure explores the price formation and price discovery, market structure and design issues, and information and its disclosure [45,78]. The trading strategies that are successful in one market

![Figure 2.1 Dynamics of price formation](image)

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often do not work well in markets with different structures. Traders therefore behave differently in different markets.

Figure 2.2: Processes that determine market dynamics

2.5 The Organization of Stock Markets

The main organizational factors that characterize real markets and influence market dynamics are: traded instruments, orders & quotes, market participants, trading sessions, execution systems, and market rules [45,78].

2.5.1 Traded Instruments

Instruments are the objects traded in a market. Instruments include several types of securities, commodities, assets and contracts. Trading instruments vary by type: real assets represent physical commodities; financial assets are instruments that represent ownership of real assets and the cash flows that they produce. Stocks are financial assets that represent ownership of corporate assets. A given stock can be traded on a market only if it qualifies for listing when it satisfies certain financial and
governance criteria stated by market rules. Certain stocks can be traded on more than one market. Stocks traded on a given market are priced according to the rules that are established on that specific market. Price, however, does not necessarily reflect the real value of a stock. The value of a stock depends on the valuation of corporate assets, liabilities and income of the corporation that they represent, and further it depends on the traders’ perception regarding how well they expect corporate managers will use the assets in the future. In this sense, stocks are not an integral part of a market where they are traded, but, they exist “outside” the market. That is: they represent the issuer company, dividends are paid on them, and their value depends on the issuer’s performance and future plans. Bonds are debt securities issued by corporations, governments, and occasionally individuals. Debtors create bonds when they borrow money. Treasury bills, Treasury notes and Treasury bonds are debt securities issued by a country. Derivative contracts are instruments that derive their values from the values of the underlying assets upon which they are based.

2.5.2 Market Regulation

Regulators create and enforce rules that facilitate trading. The Securities and Exchange Commission (SEC) is the main governmental regulating agency in the US [45]. In India, it is the Securities and Exchange Board of India (SEBI).

2.5.3 Orders and Quotes

Trading intentions are expressed by means of trade instructions called orders or by means of willingness to trade in the form of quotes [45]. Orders specify which instrument to trade, how much to trade (size of an order), whether to buy or sell (side of an order). Orders are the fundamental building blocks of trading strategies. All this information is contained in the simplest orders, called market orders. The execution of a market order depends on its size and on the liquidity currently available in the market. Market order traders pay the bid/ask spread. Orders might also specify additional conditions that the trade must satisfy. Conditions might refer to the ultimate price (limit price) that the trader accepts for an order in case of limit
orders, and they might further indicate for how long the order is valid (expressed in time or related to change in the market price), whether the order can be partially executed, etc. If price is not included in the order, the order will be executed at the market price that is valid when the order is received on the market. Buy and sell orders that cannot be executed for the moment, are entered in an order book. There is a separate order book for every stock. Order books that contain limit orders are limit order books. Traders buy or sell quoting prices and quantities. Willingness to buy is referred to as a bid quote, while willingness to sell is referred to as an ask quote or offer. Quotes include information about the name of the instrument, the trading side, the quantity and price that the traders will accept. The difference between the best (i.e. lowest) offer price and the best (i.e. highest) bid price on a market is the bid-ask spread. Traders offer liquidity when they make bids or offers, and they take liquidity when they accept bids or offers. A market is liquid when traders can trade without significant adverse effect on the price.

2.5.4 Market Participants

Depending on the tasks and role in the market, traders are classified in two main groups:

- Investors and
- Financial traders.

Traders who are not part of the market organization itself are referred to as investors. They can be individuals, mutual funds, money managers or corporate pension funds [45]. Financial traders (or financial agents) are traders endowed with special role in financial markets. They act as intermediaries, i.e. third parties in trading. They need to execute orders on behalf of the clients, or execute orders for own account in order to give other traders the opportunity to trade (i.e. to provide liquidity). Accordingly, two types of financial traders exist (Figure 2.3):

- Brokers and
- Market makers.

Brokers are primarily required to handle orders for customers. They might be allowed at some markets to trade for their own account as well. Traders use brokers
because the brokers can provide access to exchanges that they cannot access themselves. Brokers also provide access to the dealers [45]. Financial traders responsible for a good, orderly market are called market makers. Market makers allow other traders to trade when they want to trade, and make money by buying low and selling high. Market makers often are known by other names: “Specialists” from the NYSE and “Dealers” from the NASDAQ. Dealers have the obligation to commit capital to a trade in order to contribute to a liquid, orderly market. To each stock one or more market-makers can be assigned. They are responsible for the liquidity of the assigned stock.

Figure 2.3 Relation between traders

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. Market makers function only on the market itself. At present, market makers are not active in the BSE [77]. Brokers, however, can work both on the market and independently, trading through member brokers from the market organization or directly with market makers. Investors typically contact a specific broker or brokerage firm if they want to sell or invest, and ask their advice and help to place orders. However, it is also possible that investors trade directly with a market maker, for example, if they are member firms, or they trade via electronic
trading systems. A common scenario is that brokers are contacted by investors to execute an order, and they then try to trade with other brokers or market makers, like the specialist on NYSE, and the dealer with the most attractive quote on NASDAQ. Market-makers have the obligation to execute orders that arrive from outside the market-place, and need to overtake unexecuted orders from brokers. It is not always possible to execute an order immediately. The time of execution depends on market requirements, and on the market makers’ strategy and belief. Orders that cannot be immediately executed are stored in the limit order book of the market maker. Financial traders are, in fact, not always needed. Their tasks can be performed by automated order execution mechanisms as well, that do not require human intervention, as is prevalent in the markets of BSE and NSE in India [77].

2.5.5 Trading Sessions

Trading at stock markets takes place in trading sessions [45]. There are basically two types of trading sessions, based on the degree of continuity:

- Call market sessions and
- Continuous sessions.

On call-markets, trading occurs at well-specified times. During a call all trading, requests placed for a stock are aggregated and a single price is set, usually such that the trading volume is maximized. On continuous markets, trading can occur at any time the market is open. The advantage of call markets is that traders interested in a given instrument at the same time and place can easily find each other. The advantage of continuous trading is that it allows traders to arrange their trades whenever they want. Continuous trading markets are very common, with many national equity exchanges switching from call market to continuous trading with opening calls [45].

2.5.6 Execution Systems

The procedures used for matching buyers and sellers define the execution system of a market. There are three primary market structures based on the execution system applied: quote-driven, order driven and hybrid [102].
(a) **Quote-driven markets.** Often two or more execution systems are applied on a market. Such kind of markets is referred to as hybrid markets. On quote-driven markets, market makers must participate in every trade. This means that investors and brokers cannot trade with each other, they need to involve the market maker in every trade. Market makers trade for their own inventory by placing quotes at which they are willing to buy and sell. In pure quote-driven markets all liquidity is supplied by market makers. Quote-driven markets in which more market makers supply the liquidity for a given stock are also called dealer markets [45] (e.g. NASDAQ, The London Stock Exchange etc).

(b) **Order-driven markets.** On order-driven markets the orders of buyers and sellers can be brought together and cleared directly without the intermediation of market makers or dealers. Buyers and sellers have to arrange their trades based on the trading rules applied on the market. Trading requests are submitted to a central location, where they are matched [78,95]. There are many forms of order-driven markets, most of them being auction type of markets. The auction markets are also called price discovery processes, because auction reveals the price that best match buyers to sellers. In order-driven markets, traders can offer or take liquidity

*Oral Auctions.* In an oral auction, traders offer and take liquidity by calling out and accepting bids and offers. Traders must publicly express their bids, offers and acceptance. In this way all traders can participate fairly in the market. One of the best known forms of oral auction is the “persistent shout double auction” applied on the NYSE. During double auction on NYSE the current bids and offers persist. Any new bid or offer must improve on the existing one. Call outs that are improved become invalid.

*Rule-based Order Matching Systems.* On markets that apply rule-based order matching systems traders negotiate with each other by submitting and canceling orders. If the market is organized around call
sessions, then orders will be collected before a call and there is one attempt made to arrange all trades at the end of a call. In continuous trading markets the system attempts to arrange trades whenever new orders arrive. Based on the rule applied to determine prices of trading arrangements, the main types of markets are single price auctions and continuous two-sided auctions.

- **Single Price Auctions.** In a single price auction, all trades take place simultaneously at the same market clearing price. If the buy and sell order in a feasible trade have different prices (i.e. the price of the buy order is higher than the price of the sell order), the orders can be filled at any of these prices, or at any price between them. The final price in this case will be determined by trading rules.

- **Continuous Two-sided Auctions.** In a continuous two-sided auction, orders that cannot be filled are stored in an order book. Incoming sell orders are compared with the best bid and incoming buy orders are compared with the best offer from the order book. If a match is possible, trade is conducted at the price of the order from the order book. If the trade does not completely fill the new order, the system matches the remainder of the order from the next highest ranking order from the order book on the corresponding side.

Order-driven markets are very common. All markets that conduct electronic auctions or open-outcry auctions are order-driven markets. On call markets typically single-price auctions are conducted. These types of call-sessions are referred to as call-auctions. On many continuous markets it is possible to arrange trades via electronic continuous two-sided auctions. Both quote-driven and order-driven markets can be further characterized as brokered markets if brokers actively search to match buyers and sellers. Brokers are either asked by investors (their clients) to fill their orders or initiate orders themselves by suggesting trades to their clients. Brokers are, for example, often needed on order-driven markets for an effective creation of liquidity.
(c) Hybrid markets. Hybrid markets do not apply a single execution system, but they combine them. In such a case, the dominating system defines the market type. The NASDAQ stock market is, for example, a quote-driven market, but sometimes traders can directly trade together. Many continuous markets are basically order-driven markets but if there is not enough activity intermediaries need to intervene as market makers [95]. This is the case if there is order imbalance (there are no orders on one of the trading sides), or if the bid-ask spread becomes too wide. The BSE and NSE are essentially an order-driven market.

2.5.7 Market Rules

On every market, rules specify how buyers and sellers can arrange their trades. The set of rules adopted on a market is called the protocol. Rules regulate the organization of trades, the trade prices, and determine the quantity and quality of information provided to market participants. Rules restrict the allowed minimum and maximum difference between the bid and ask prices of a dealer’s quote, called as bid-ask spread, the minimum and maximum difference between two consecutive bid quotes and ask quotes, the unit by which traders can vary their quotes (e.g. decimals) called tick-size. The order in which orders can be filled also depends on regulations: earlier placed orders, or orders at better prices might have priority. The quantity and quality of information provided to the market participants during the trading process [78], the extent of dissemination and speed of dissemination are all regulated by market rules. Information is classified as pre-trade or post-trade based on the timing of its availability. Pre-trade information refers to information a-priori available for traders, such as: quotes, the content of the limit order book, degree of anonymity. Post-trade information refers to the transactions made, to the publication of prices, etc. An example of post-trade information is transaction data. On many markets there must be some delay before transaction data is published. The way information is disseminated on a market influences the degree of transparency of that market. The organizational factors described above state how trades can be conducted and thus, how prices can be formed on a market. Accordingly, the type of execution system by which the final price is determined on a specific market is
known. However, the detailed process behind the actual price formation and the participants’ behavior is not observable.

2.6 Price Formation and Behavioral Aspects

The dynamics of stock, the processes and behavioral aspects that influence market dynamics is discussed. The tasks and responsibilities of market participants decides the behavioral aspects i.e. factors related to the trading behavior of market participants, such as the way market participants decide which stocks to trade, the way they determine the parameters of their orders and quotes, their timing regarding when to place orders, when and how to determine the parameters of a transaction, if that is not unequivocally defined by the trading rules, and so on. Possible ways of price formation through the behavior of market participants is seen by tracking step by step how orders might be formed and how they might trigger market prices.

2.6.1 Order Initiation and the Behavior of Investors

Orders can be initiated by investors or by financial agents trading for their own account, trying to keep or reallocate a certain level of inventory, or trying to ensure liquidity [45]. Traders can develop a variety of investment strategies analyzing the market indicators. Indicators are characterized as either technical or fundamental. Fundamental indicators are related to the basic intrinsic value, also referred to as fundamental value of a stock, and as such, depend mainly on the underlying economic factors, like the performance of the issuer. Technical indicators refer to assumed statistical features of the historical data. Based on the type of data that is used by traders for forecasting, two main types of investors are differentiated: fundamentalists and technical analysts (or chartists). Based on the policy and forecast, traders or their advisors implement the investment strategy by determining how to allocate available funds across different markets, asset classes, and assets depending on the investor’s attitude to risk. Trading instruments of different types are categorized in asset classes, such as real assets, risk-free assets paying constant interest rate, and stocks paying varying dividends. Regardless of the investment strategy used, the portfolio construction results in asset allocation, and the specific
assets and weights within each asset class. The difference between the current portfolio and the required portfolio determines the parameters of the orders that traders will place: the identity of the traded assets, the size and side of the orders. When placing an order, traders should have in mind an ultimate price at which they are willing to buy/sell the selected stocks. The price depends heavily on the expectations given by the investment strategy. At markets where limit orders can be placed, traders can quote a price (limit price) at which they are willing to trade in the worst case. Traders might also decide to place market orders, and then, the price that they are not willing to exceed can be determined by the right timing of the placement of the order. In general, as described by Reilly and Brown [95], the portfolio management process involves four main, highly interrelated tasks:

- Construction of a policy statement,
- Determination of the investment strategy to meet the policy statement guidelines,
- Construction and maintenance of the portfolio, and
- Monitoring.

These tasks identify generic and varying aspects of traders’ behavior when placing orders.

2.6.1.1 Policy Statement

The policy statement is a road map that specifies the investment goals, constraints and risks investors are willing to take. It depends on the expectations and experience of the investors and it is determined taking into account the investors’ short-term and long-term needs. The policy should be updated from time to time given that needs change over time. Three main factors drive the policy statement: the investment goals, investment constraints and risk. Investors can have a variety of objectives changing over time. Objectives are stated for different time-horizons and are of varying importance. There are several constraints those influence investment objectives, including: liquidity needs, time-horizon, tax concerns, legal and regulatory factors, unique needs and preferences. A close relationship exists between
the investors’ time-horizon and liquidity needs: near-term goals might require quick conversion to cash and thus more liquidity. In order to achieve their objectives, investors need to take risk. People are willing to take different grades of risk. That is, they have different attitudes to risk. An investor’s attitude to risk is influenced by personality, financial constraints, and personal preferences. In addition, the priority and the time-horizon of an objective might exert a big influence on the attitude to risk: long-term investment horizons can usually tolerate more risk, while investors with short-term time horizons favor less risk.

2.6.1.2 Investment Strategy

In order to achieve the investment objectives stated in the policy statement, traders can develop a variety of investment strategies. The development of a strategy includes the study of financial, economic, political and social conditions and aims to forecast future prices at a certain time-horizon. Many indicators exist that traders use for analysis in this sense. Many studies are devoted to analyze how and whether various indicators can be used to describe and forecast financial time series. A thorough overview of measures and possible relationships between these is given by Haugen [47]. Indicators are characterized as either technical or fundamental. Fundamental indicators are related to the basic intrinsic value, also referred to as fundamental value of a stock, and as such, depend mainly on the underlying economic factors [95], like the performance of the issuer. Technical indicators refer to assumed statistical features of the historical data. Arbitrary many ways exist to consider and combine diverse indicators in order to have a possible projection into the future. Based on the type of data that is used by traders for forecasting, two main types of investors are differentiated: fundamentalists and technical analysts (or chartists). In the literature they are also referred to as informed traders and noise traders, respectively.

2.6.1.3 Portfolio Maintenance

Based on the policy and forecast, traders or their advisors implement the investment strategy by determining how to allocate available funds across different markets, asset classes, and assets depending on the investor’s attitude to risk.
2.6.1.4 Monitoring

Monitoring is, in fact, conducted in combination with all the other processes of portfolio management. Monitoring implies periodic reconsideration of the various phases. Investors monitor their needs and the market conditions, and evaluate the portfolio performance from time to time, compare it to expectations, and modify the policy statement and/or the investment strategy if they think it is necessary. Monitoring includes thus, performance analysis, and assimilation of new information. Modified statements and strategies reflect the adaptive behavior of the traders.

2.6.1.5 Time Horizon

During the various stages of the portfolio management process a variety of time factors, related to different decision problems, play an important role [45]. The time factor can refer to the time-horizon of the investment objectives, to the forecast horizon of the investment strategies, to the time interval traders look back in past for relevant historical data in order to forecast etc.

2.7 Order Flow, Role and Behavior of Financial Traders

This subsection deals with tracing the orders on the various routes they can follow, based on the organization of the market where they are placed and executed, and on the role and behavior of financial traders who execute them. First, markets in which brokers can interact and the way orders might be processed by brokers are discussed, followed by automated execution mechanisms and finally, the tasks of market makers are analyzed.

2.7.1 Order Execution and the Role of Brokers

According to their role, brokers are committed to clear orders on behalf of the investors. Their main task is thus to receive and execute orders placed by investors (Figure 2.4). In addition, they might also place orders for their own account if...
allowed.

Figure 2.4: Tracking orders

Like investors, brokers continually monitor and analyze the market conditions which influence them in making decisions. The way brokers decide to select and execute orders depends on the execution systems applied on the market where they interact. There are basically three main possibilities a broker can choose from (Figure 2.4) depending on the rules and the execution system that apply on that market [102].

2.7.2 Order Execution and the Role of Market Makers

While placing an order always involves traders, the execution of orders does not necessarily require a trader, but can be automated. Central order execution at call sessions might be conducted by a special financial trader, e.g. a market maker but often an automated system is used to match orders and find an equilibrium point. Similarly, a mechanism on continuous markets where limit orders are stored if they cannot be executed and new orders are matched against the best quotes, can be solved by an automated order matching systems, like a continuous electronic system operating continuously [45]. The role and behavior of market makers are seen next, as summarized in [78,102]. They perform the following tasks:

(a) Permit continuous trading by overcoming the asynchronous timing of investor orders;
(b) Monitor the market through quoting bid and ask prices at which they buy and sell stocks;
(c) Set prices: adjust the bid-ask spread to the changing market conditions;
(d) Provide liquidity: provide additional liquidity for less liquid stocks;
(e) Complement the supply of liquidity at the time of call-auctions.

Summarizing the tasks above, market makers are responsible for a good functioning of the markets [45]. For this reason, they need to place additional orders and to execute received orders as soon as possible. Further, they need to maintain bid and ask quotes on continuous markets that on the one hand reflect market conditions, and on the other hand encourage trading.

2.7.3 Execution of Orders on Call Markets

During call market sessions, trading takes place at well defined times when all interested traders need to send their orders during a given time interval to a central execution system. In case of call auctions, orders are accumulated and matched at a single price at some equilibrium. The equilibrium point in most of the cases aims to maximize trading volume, or to minimize excess demand. The key factor distinguishing the mechanisms of call-auctions, and the main decision problem to be solved by market makers or by automated execution systems on these type of markets is thus, how to determine the equilibrium price. A Walrasian auction is a preferred option for determination of the equilibrium price [63,90].

2.8 Execution of Orders on Continuous Markets

During continuous trading sessions, market makers need to determine bid and ask quotes. When market makers receive an order, they check whether it matches the quoted bid (in case of a sell order) or ask (in case of a buy order). If it matches they clear the order at the quoted price and charge the actual transaction costs, otherwise they enter the new order into the limit order book. Besides new order arrivals, inactivity on the market, competitive behavior, belief, or the arrival of some information can cause the market maker to update the bid and ask quotes. The main decisions that market makers face on continuous markets is thus related to:
(a) Arriving at the values of the new quotes so as to reflect the limit orders, the market makers’ position and to ensure a liquid and fair market.

(b) Set the timing of the new quotes.

(c) Management of the limit order book, as to how and when to execute orders entered in the limit order book.

The most simple solution for defining a quote is to take the highest bid and lowest ask orders from the order book, as quotes. However, most likely, real bid-ask setting strategies of market makers are more complicated, as they depend, among others, on the content of the limit order book and on the position of the market maker. This decision would depend to a large extent on the strategy adopted.

2.9 Challenges to Modeling Market Dynamics

The difficulty to understand market dynamics is caused by the fact that the details behind these alternatives are complex and varied. The final market price does not entirely depend on the originally quoted price of an order placed by an investor. The hardly observable aspects of the market mechanisms, and their complexity, are reasons behind the difficulty to understand market dynamics. This is why representations of markets have to be designed incorporating assumptions regarding hardly observable aspects [45].

2.10 Characteristics of a Good Market

The most important characteristics of a good market are [95]:

(a) Transparency. Traders expect timely and accurate information on the prices and volume of past transactions, and on the current outstanding bids and offers in order to be able to determine an appropriate price.

(b) Liquidity. Liquidity refers to the ability to buy and sell an instrument quickly at a fairly certain price, that does not differ substantially from previous transaction prices assuming no new substantial information is revealed.

(c) Low transaction costs. Traders prefer markets with lower transaction costs to markets with higher transaction costs. Investors will normally not trade if the costs of the trade are higher than the difference in value between what they
give up and what they receive. Markets where minimal transaction costs are charged are characterized as internally efficient.

(d) **Informational efficiency.** A market in which prices reflect all available information is characterized as being information efficient.

The first three measures of a good market, namely transparency, liquidity and low transactions costs, can be more or less directly manipulated through the organizational aspects of the market, such as trading rules, execution systems and trading sessions.

### 2.11 Information in Markets

The main driving force of market dynamics is information [45]. Information on markets is classified along two dimensions: its source and its grade of dissemination.

Based on their source, two categories of information are differentiated, namely:

(a) **Based on Source.**

- **Market information.** Market information, also known as trading information, refers to currently available information generated by the market and historical values. It includes knowledge of the current quotes, last transaction data, and contents of the limit order book.

- **Fundamental information.** Fundamental information pertains to the determinants of future share value. It includes information concerning current earnings, forecasts, strategic business and economic condition [45].

(b) **Based on its availability.** Three categories of information are defined accordingly, based on the extent to which information is disseminated:

- **Public Information.** Public information refers to information that is widely disseminated and is readily available to everyone (freely or for cost). It includes market information, and fundamental information such as earnings and dividend announcements, price-to-earnings (P/E) ratios, dividend-yield (D/P) ratios, price-book value ratios (P/BV), stock splits, news about the economy, political news etc.
• **Private Information.** Private information is fundamental information (current earnings, forecasts, strategic business and economic condition etc) possessed individually based on own analysis.

• **Inside Information.** Inside information is only known by people in a special position.

### 2.12 Market Efficiency

An efficient market is defined as a market in which prices always “fully reflect” all available information, and is known as the efficient market hypothesis (EMH). Depending on the type of information, that is to be reflected into prices, three variants of efficiency have been proposed in the form of hypotheses [30]:

(a) Weak-form EMH is concerned with the full reflection of all past market information (current quotes, last transaction data, contents of the limit order book, dividends and results declared etc).

(b) Semi strong-form EMH is concerned with the full reflection of all public information (earnings, dividend, P/E ratio, P/BV etc).

(c) Strong-form EMH is concerned with the full reflection of all information from public sources (earnings, dividend, P/E ratio, P/BV etc) and private sources (current earnings, forecasts, strategic business condition etc).

In an efficient market prices adjust rapidly to the release of new information [95]. Therefore market prices reflect all information so that no one can predict future price changes [45]. In an efficient market investors cannot realize excess returns. In an efficient market investors are not able to consistently derive above-average risk adjusted profits. And in a perfectly efficient market, prices follow a random walk.

### 2.13 Theories of Modern Finance

The very first models proposed to explain market dynamics use mathematics as a tool to describe traders’ behavior and financial time series. The most popular paradigms developed include the portfolio optimization theory by Markowitz [82], the Capital Asset Pricing Model (CAPM) by Sharpe [103], the Option Pricing
Model (OPM), the Expected Utility Theory (EUT) and the Efficient Market Hypothesis (EMH) [30]. All the models assume that [8]:

(a) **All traders are rational.** Rational traders always make the most optimal choice in a given situation. The market is cleared at equilibrium, and the mechanics of trading is ignored. Equilibrium is most often defined at the price at which demand equals offer. This is the price at which orders are executed, i.e. it is assumed that the trading mechanism does not affect the resulting equilibrium.

(b) **Markets are considered efficient.** In financial markets it is not possible to earn abnormal profits, other than by chance, by exploring some set of information.

(c) **Trading Mechanism Vs Equilibrium.** As far as order execution mechanisms and price formation are concerned, in theoretical market models, equilibrium is central, and the mechanics of trading is ignored. Implicit in this approach is the assumption that the trading mechanism does not affect the resulting equilibrium: that is, whatever trading mechanism is employed, the same equilibrium would arise [88].

### 2.14 Approaches for Studying Market Dynamics

In order to understand and explain the dynamics of financial markets, price dynamics are analyzed. Several methods have been proposed that try to describe the properties of price series. Approaches include analytical models, empirical testing, experiments and computer simulations. According to the theoretical models, market participants are assumed to be rational, prices are formed at equilibrium, and markets are efficient. A number of approaches have been proposed to test whether markets operate as described by modern finance theory [30,82,88,103]. Approaches include empirical studies, experimental economics, and the market microstructure approach. Empirical studies primarily focus on market quality, in particular on efficiency. Traders’ behavior is central in experimental economics. Finally, market structures and the effect of trading mechanisms on the price dynamics are closely
analyzed and described in the market microstructure literature. Table 2.1 gives a broad comparison of these approaches [13,30,82,103].

Table 2.1: Comparison of approaches used to study market dynamics

<table>
<thead>
<tr>
<th>Approach</th>
<th>Price Formation</th>
<th>Trader’s behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical( analytical)</td>
<td>Simple; linear at equilibrium</td>
<td>Rational</td>
</tr>
<tr>
<td>Empirical</td>
<td>Analyse statistical properties of real data</td>
<td>No special attention paid</td>
</tr>
<tr>
<td>Market microstructure</td>
<td>On specific trading mechanism</td>
<td>Investors with asymmetric information/inventory management; learning market maker</td>
</tr>
<tr>
<td>Microscopic and Agent based simulation</td>
<td>Emerges from interaction of individuals</td>
<td>Boundedly rational and heterogeneous</td>
</tr>
</tbody>
</table>

2.15 Market Anomalies and Empirical Studies

In order to determine how efficient various markets are, numerous empirical studies have been conducted. Empirical studies test whether theoretical models correspond to reality by taking real data and trying to fit them to the model tested. In contrast to the theoretical approach, empirical studies investigate the real data. This approach aims to describe and analyze properties of market data. Early empirical tests supported the theoretical models. However, empirical regularities have been uncovered in the pricing of stocks, not predicted by traditional models and are referred to as anomalies [66]. Statistical properties that reveal non-random features of historical data are referred to as stylized facts. Examples are excess volatility, heavy tails, no autocorrelation, volatility clusters and volume-volatility correlation
Heavy tails attributes to the distribution of returns displaying fat tails with positive excess kurtosis. Further, it has also been observed that trading volume is positively correlated to market volatility and volatility clusters have been reported [80], where it is noted that large changes tend to be followed by large changes of either sign and small changes tend to be followed by small changes. Findings of empirical research are contradictory and the significance of anomalies is controversial. Whether anomalies are persistent and investors can exploit them to earn excess return in the future is subject to debate. On the other hand, advocates of theoretical finance, maintain that anomalies are not of a sufficient magnitude to suggest that this fact can be exploited. Most importantly, transaction costs are likely to offset any advantage that may arise. Despite this controversy, empirical findings rarely support theoretical models, and they suggest that there is predictability in the prices. The question is whether this proves that markets are not efficient, or predictability is the consequence of other properties, such as market structure, frictions, or changing conditions.

2.16 Behavioral Finance and Experimental Economics

Empirical findings suggest that markets do not necessarily behave according to the theoretical models suggested. A possible reason behind this phenomenon might lie in the simplifying assumptions behind these models. Behavioral finance and experimental economics investigate whether the assumptions on homogeneous rational decision-making, utility maximization and a priori knowledge of utility functions and alternatives are valid [109]. Findings of experiments suggest heterogeneity and bounded rationality of traders, however, results are often questionable because of biased features included in the experimental process, which can influence the subjects’ behavior even if only subconsciously. For example, as postulated by Phelan and Reynolds [93]: “The mere observation of people may lead them to modify their behavior and if information about behavior is to be published this may also have an effect.” Other possible biases are discussed in [96]. Another question that arises with respect to experiments is whether and how findings can be calibrated to real data [65].
2.17 Market Microstructure Models

While experimental economics try to reveal the hardly observable aspects of traders’ behavior, market microstructure literature is concerned with the hardly observable price formation mechanisms [63]. Traditional theoretical models assume that prices are formed at equilibrium and markets are cleared at this price. In these models it is not of interest how this market clearing was achieved. In contrast to the traditional equilibrium models that ignore the mechanics of trading, market microstructure literature analyzes how specific trading mechanisms affect the price formation process [88]. According to the market microstructure theories, prices need not equal full-information expectations because of a variety of frictions. A central question of this approach is concerned with how various frictions and departures from symmetric information, i.e. the fact that participants do not possess the same information, affect the trading process [78]. Few of the best known theoretical microstructure models which study the process by which prices come to impound new information are:

- Glosten and Milgrom model [39]
- Extended Glosten and Milgrom Model [26]
- Levy, Levy, and Solomon Model [71]
- LeBaron’s Model [63].

2.18 Recent Approaches for Study of Financial Markets

Recent promising approaches propose a bottom-up understanding of financial markets. In contrast to other approaches they pay attention to individual interactions and study the emergent properties generated as the results of these interactions. The main observation behind the constructive approaches is that economies are recognized as complex dynamic systems. This feature is explained by Tesfatsion [116] as follows: “Large numbers of micro agents engage repeatedly in local interactions, giving rise to global regularities such as employment and growth rates, income distributions, market institutions, and social conventions. These global regularities in turn feed back into the determination of local interactions. The result
is an intricate system of interdependent feedback loops connecting micro behaviors, interaction patterns, and global regularities”. There are three main approaches:

(a) **Nonlinear Economic Dynamics Approach.** The area of nonlinear economic dynamics assumes nonlinear price formation and boundedly rational traders, whose belief about efficiency co-evolves with price. Models within the nonlinear approach are referred to as dynamic heterogeneous agent models. Within this approach price formation is based on nonlinear rules rather than linear equations. Further, traders are assumed to be boundedly rational. Moreover, traders’ strategies co-evolve with markets. Studies for describing and analyzing market dynamics within this area, typically apply a mixture of analytic and computational tools.

(b) **Microscopic Simulation.** In microscopic simulation and ACE, the focus is on individual interactions. The idea behind microscopic simulation is to model the system in question as a set of microscopic elements and define microscopic interactions between them. This approach then investigates how observed macroscopic features emerge from the interaction of these microscopic elements. This method is now being applied in social sciences as well. Levy et al. [71] have done extensive work in this area.

(c) **Agent-Based Computational Economics (ACE)**  
Another approach to constructive understanding of economic theory, is the rapidly expanding area of agent-based computational economics (ACE). ACE is defined by Tesfatsion as “the computational study of economic processes modeled as dynamic systems of interacting agents” [113,114,116]. Agent-based market models attempt to explain the origins of observed properties of market prices in terms of simple, stylized behavioral rules of market participants. In recent years, studying stock markets using multi-agent based models has become a promising research area due to the fact that this methodology reflects the nature of the stock market where heterogeneous investors with various expectations and different levels of rationality interact with each other through the market [19].
Microscopic simulation and agent-based computational economics ultimately apply the same paradigm: constructive understanding, the importance of individuals and their interactions; they just emerged from different areas of science.

2.19 Behavioral Bias

The individual investors, who are prone to biases in judgment and use various heuristics, lead to anomalies on the market level. This aspect has been explored within the field of behavioral finance. Behavioral finance builds itself upon two pillars: limits to arbitrage and psychology [4]. While psychology lists a number of possible deviations from rationality, the limits to arbitrage argue that rational investors may not be able to exploit opportunities created by irrational investors. If irrational investors (noise traders) create dislocations in asset prices (departures from fundamental values), rational investors (arbitrageurs) should be able to correct this mispricing through the process of arbitrage. However, it has been recognized in literature that arbitrage strategies in real financial markets (as opposed to the strict definition of arbitrage) can involve cost, risk, or various constraints, so the inefficiencies may persist for a long period of time. Since agent-based models can easily accommodate complex learning behavior, asymmetric information, heterogeneous preferences, and ad hoc heuristics, such simulations are particularly suitable to test and generate various behavioral hypotheses. According to LeBaron [70], “It is important to note that agent-based technologies are well suited for testing behavioral theories. They can answer two key questions that should be asked of any behavioral structure. First, how well do behavioral biases hold up under aggregation, and second which types of biases will survive in a co evolutionary struggle against others. Therefore, the connection between agent-based approaches and behavioral approaches will probably become more intertwined as both fields progress”. Studying behavior of market participants is important because of its potential impact on asset prices and the dynamics of financial markets. Agent-based market models have been proposed as a tool for studying such impact of individual investor behavior. Various behavioral phenomena have been studied, such as overconfidence, sentiment (optimism, pessimism), loss aversion, biased self-attribution, and recency and primacy effects, within existing agent-based ASM. Behavioral finance approach
focuses on realistic elements of the behavior of market participants, as opposed to normative financial theories that rely on very strong assumptions of investor rationality, which have been empirically questioned or disproved.

2.19.1 Behavioral Biases in Investor Decision Making

The question of investor decision making is in financial literature often conceptualized as a process consisting of different paradigms. A review on the profiling of investors based on the following behavioral issues is presented below:

(a) Risk attitude.
(b) Portfolio allocation.
(c) Portfolio management.
(d) Information processing and learning.
(e) Social interaction.
(f) The role of emotions
(g) Heuristics, biases, and departures from rationality.

2.19.2 Risk Attitude

The crucial concept for investments, and decision making in general, is the concept of risk. The most influential theories for decisions under risk and uncertainty are known as Expected Utility Theory [5,120], Prospect Theory [52], Rank-Dependent Utility Theory [94,101], and Cumulative Prospect Theory [118]. Traditional economics and finance have been dominated by these probabilistic models of uncertainty. However, other theories for dealing with uncertainty, ambiguity, or vagueness exist: e.g. Fuzzy Set Theory of Zadeh [125], and Rough Set Theory of Pawlak [92]. A decision maker’s attitude towards risk can be characterized as risk-aversion, risk-seeking (risk-tolerance, risk-taking, risk-loving), or risk-neutrality; and can be defined in a classical sense as a preference between a risky prospect and its expected value (the method of revealed preference). In these theoretical considerations risk attitude is usually captured through the curvature of utility function, or alternatively, through nonlinear weighting of probabilities.
Another strong empirical phenomenon that is driving risk aversion to a large extent is known as “loss aversion” [52, 82]. “Losses loom larger than gains” and while people are typically risk-averse for gains, they are risk-seeking in the domain of losses [52]. This highlights reference dependence, i.e. the importance of reference point against which outcomes are coded as losses or gains. Furthermore, risk attitude can change depending on the outcomes of previous decisions. Thaler and Johnson [117] found that previous gains increase risk-seeking behavior. Risk in investments is usually considered as the standard deviation of asset returns. Volatility and variance are seen as common measures of risk. Kurtosis, on the other hand, was perceived as risk reducing. Investor perception of risk in security valuation can be biased [108]. Ganzach [33] found in experiments that judgments of risk and return for familiar financial assets were consistent with their ecological values (a positive relationship between risk and return).

2.19.3 Portfolio Allocation

Behavioral finance takes a descriptive perspective, by studying how individual investors actually allocate their portfolios. In portfolio theory one of the crucial concepts is diversification, a risk-management technique where various investments are combined in order to reduce the risk of the portfolio. However, many investors do not (sufficiently) diversify their portfolios. This may be due to beliefs that the risk is defined at the level of an individual asset rather than the portfolio level, and that it can be avoided by hedging techniques [10]. It was also found that young active investors are over focused and inclined towards concentrated, undiversified portfolios, which might be a manifestation of overconfidence.

2.19.4 Portfolio Management

Behavioral literature focuses on how individual investors manage (or make changes to) their portfolios. A common tendency to hold losers too long and sell winners too soon, has been labeled by Shefrin and Statman as the disposition effect [105]. They attributed their findings to loss aversion, the issue of self-control, and the desire to avoid regret. Odean found that a particular class of investors sells winners more readily than losers [86]. Even when the alternative rational
motivations are controlled, these investors continue to prefer selling winners and holding losers. Their behavior is consistent with two behavioral hypotheses: the prospect theory, and a mistaken belief that winners and losers will mean revert. This investor behavior appears not to be motivated by a desire to rebalance portfolios or by a reluctance to incur the higher trading costs of low priced stocks. It is also not justified by subsequent performance, as, in fact, it leads to lower returns [86]. Investors trade too much due to their overconfidence. For successful investors this overconfidence can be reinforced through self-attribution bias, i.e. belief that their trading success should be attributed mostly to their own abilities. While some investors may trade too much and often change their strategies, others may exhibit the tendency of “doing nothing or maintaining one’s current or previous decision.” This is how Samuelson and Zeckhauser defined the status quo bias [99]. Explanations for the status quo bias fall into three main categories. The effect may be seen as the consequence of (1) rational decision making in the presence of transition costs and/or uncertainty; (2) cognitive misperceptions; and (3) psychological commitment stemming from misperceived sunk costs, regret avoidance, or a drive for consistency. The status quo is related to loss aversion (framing as gains and losses) in the sense that current position (status quo) is seen as the reference point. Other explanations, such as anchoring, sunk costs, regret avoidance, the drive for consistency, the avoidance of cognitive dissonance, and the illusion of control, may contribute to the perseverance of the status quo bias. It is also related to the influence of default option on choices.

2.19.5 Information Processing and Learning

Market participants are exposed to a constant flow of information, ranging from quantitative financial data to financial news in the media, socially exchanged opinions and recommendations. Processing all this information is a daunting task, so it would not be surprising that during this process people apply many heuristics. According to the representativeness heuristic, people may overreact to a series of evidences, and see patterns where they do not exist. However, people can sometimes under react to news, i.e. in the light of a new evidence they update their beliefs conservatively, and not in a fully Bayesian manner. Processing information from
the investment environment is important as it gives inputs for decision making and belief updating, gives feedback on investment strategies, and fosters learning. However, the confirmation bias may play an important role in how investors acquire and process this information. It suggests that people have a tendency to search for information that supports their current beliefs and decisions, while neglecting information that confronts those beliefs. An interesting finding is that the information speed, expected market impact, and anticipated market surprise are rated as more important than the reliability of the source, and the accuracy of information.

2.19.6 Social Interaction

Information is transmitted by prices, volume, or corporate actions. However, person-to-person and media contagion of ideas and behavior also seems important [48]. In a survey of individual investors, Shiller and Pound [110] found that almost all of the investors who bought a particular stock had their attention drawn to it through direct interpersonal communication [107]. The influence of conversation on trading may arise from individuals’ overconfidence about their ability to distinguish pertinent information from noise or propaganda [48]. Social psychology provides evidence of various social effects which might be important in the context of financial markets as well. “Conformity effect”, or the tendency of people to conform to the judgment and behavior of others, was studied by Asch [1]. Bond and Smith [9] confirmed the conformity effect, showed its historical change, and emphasized its cultural dependence. Other effects found in the social context are fundamental attribution error and false consensus effect [48].

2.19.7 The Role of Emotions

Emotions have powerful effects on decisions, and decision outcomes have powerful effects on emotions [83]. Emotions can have both a pre-decision and post-decision effect. Most of the research focused on a one-dimensional model in which a pre-decision emotion can be either positive or negative. However, a more detailed approach is needed given the variety and domain-specificity of emotions [83]. Positive emotions are shown to increase creativity and information integration,
promote variety seeking, but also cause overestimation of the likelihood of favorable events, and underestimation of the likelihood of negative events. Negative emotions promote narrowing of attention and failure to search for alternatives. One of the most studied emotions that can follow a decision is the feeling of regret. Gilovich and Medvec [37] showed that in the short run people experience more regret for actions rather than inaction, while in the long run they experience more regret for their inactions. Thus, emotion and cognition both play a crucial role in decision making.

2.19.8 Heuristics and Biases

Much of the behavioral finance literature focuses on individual investor psychology, particularly the use of heuristics and various biases in judgment. Milan L. has organized and presented these heuristics and biases as a taxonomy [75]. A traditional approach describes decisions as choices between risky prospects. A decision maker forms beliefs about probabilities of events and about utilities of outcomes contingent on those events. Finally, he or she makes preferences between risky options. Biases can arise both in the process of forming beliefs and preferences. In the more general sense, a bias can be defined as a departure from normative, optimal, or rational behavior. Heuristics are mechanisms (rules, strategies) for processing information to arrive at a quick (not necessarily optimal) result following little effort [40]. Tversky and Kahneman investigated heuristics that people often employ when making decisions under uncertainty [118]. Heuristics are useful because they make the difficult task of assessing the probabilities related to uncertain events much easier. However, these heuristics can also lead to systematic biases in judgment. Importantly, heuristics and biases should not be treated as synonymous, even though they are found reflected together in behavioral finance literature. Not all biases arise from heuristics, and, also, not always the use of heuristics leads to biases. However, a heuristic behavior may actually result in a successful performance compared to an optimal strategy. A natural way for people to think about money is in terms of nominal rather than inflation-adjusted values [105]. Thus, under hyperinflation, people will view nominal wage increase more favorably than it really is. The listing of some of the most known heuristics, biases
and effects found in behavioral finance literature can be found in [75]. His exposition on loss aversion, overconfidence and regret, are reproduced below:

(a) **Loss Aversion.** Loss aversion is a pervasive phenomenon in human decision making under risk and uncertainty, according to which people are more sensitive to losses than gains. It plays a crucial role in Prospect Theory [118]. A typical financial example is in investors’ difficulty to realize losses. People would hope that markets will work in their advantage and that they will be able to terminate their investment without incurring any losses [105].

(b) **Overconfidence.** Overconfident people are not well calibrated. In their predictions they set confidence bands overly narrow, which means they get surprised more frequently than they anticipated [105]. This type of overconfidence is known as “miscalibration”. A more general definition of overconfidence is the one by which people overestimate their own capabilities, usually with respect to capabilities of other people on average. This is also known as “better-than-average overconfidence”. In financial markets overconfident investors are considered those who actively trade in such a way that the difference between the stocks they buy and those they sell does not cover transaction costs [86].

(c) **Regret.** Regret is the emotion experienced for not having made the right decision. It is the feeling of responsibility for loss [86]. In a financial context the minimization of possible future regret plays an important role in portfolio allocation. It is also related with preference for dividends in financing consumer expenditures, because selling a stock that may rise in the future carries a huge potential for regret.

(d) **Sentiments.** One of the key characteristics that govern investor behavior is the optimism or pessimism of the investors. The link between asset valuation and investor sentiment has been the subject of considerable debate in the finance, and has been studied in the context of mispricing (departures from the fundamentals) [12], the limits of arbitrage [27], as well as the under reaction and overreaction of stock prices [4]. Sentiment, in the case of optimism, gives more weight to higher returns observed in the memory
window, while in the case of pessimism; sentiment gives more weight to the lower returns.

(e) **Recency and Primacy Effects.** In this case, timing aspects of observed returns is explicitly taken into account. In psychological literature two inverse effects have been observed in the way people give salience to received stimuli or observations depending on their serial position [84]. These cognitive biases are known as recency and primacy effects. While primacy refers to the tendency to give more weight to the first received piece of information (the oldest one), recency describes the tendency to give more weight to the last received piece of information (the most recent one). Recency effects have been studied in the financial literature in relation with the overreaction hypothesis and overreaction is attributed to the psychological phenomenon of recency. When processing information, people tend to overweigh recent information compared with their prior belief. Thus, traders who are not sure of the intrinsic value of a stock will be too optimistic about its value when the firm is winning and too pessimistic when it is losing [87]. The empirical finding that a portfolio composed of past losers eventually beats a portfolio composed of past winners is considered an evidence for such overreaction.

(f) **Self-Attribution Bias and Loss Aversion.** It appears that the markets can also influence the confidence of investors: the overconfidence of successful investors can be reinforced through self-attribution bias, i.e. a belief that their trading success should be attributed mostly to their own abilities [86].

An overview of behavioral biases in investor decision making has been given in [75]. The topic of behavioral finance has been introduced and the main motivation and challenges explained. While psychology studies behavioral biases in order to understand how they arise and manifest themselves, behavioral finance aims to understand how they aggregate across individuals, whether they have impact on the market dynamics and ramifications for investor performance. In order to study such implications of investor biases it is important to understand the most relevant aspects of investor behavior as well as the environment in which they are operating. Milan
L. has developed a descriptive conceptual model of an individual investor and given a structure to this body of knowledge. In this work, however, individual behavior is being directly implemented into the computational model of LLS.

### 2.20 A Cognitive Model of the Individual Investor

A cognitive model of an investor is given below:

![Figure 2.5: A cognitive model of the individual investor](image)

The central part the cognitive model of the investor (Figure 2.5) is based on a two-dimensional framework of neural functioning proposed by Camerer et al. in [15]. This is conceived as a central information processing and decision making unit that interacts with the investment environment through the perception-interaction-action interface, and is influenced by a number of variables, including risk attitude, time preference, strategies, goals, motivation, emotions, heuristics and biases, personality, demographics and other factors.

### 2.21 Statistical Properties of Stock Markets

One way of examining ASM is by comparing their outputs (i.e. generated time-series) with real-world financial data. Assessing to what extent these artificial time-series are realistic is usually done by finding similarity between their statistical
properties and the statistical properties of empirical data. A set of properties, found across many financial instruments, markets and time periods, has been observed by independent studies and classified as “stylized facts” [23] which are listed below:

(a) **Heavy tails.** The unconditional distribution of returns tends to be non-Gaussian, sharp peaked and heavy tailed.

(b) **Gain/loss asymmetry.** It is possible to observe large downward movements in stock prices and stock index values, but not equally large upward movements (exceptions are exchange markets which are quite symmetrical).

(c) **Aggregational Gaussianity.** The shape of the distribution is not the same for all time scales; as the time scale is increased (returns are calculated over a longer period) the distribution becomes more normal.

(d) **Conditional heavy tails.** Returns that have been corrected for volatility clustering still exhibit some degree of heavy tails.

(e) **Absence of autocorrelations.** (Linear) autocorrelations in asset returns are often insignificant, except for very high-frequency data where microstructure starts playing a role.

(f) **Volatility clustering.** Nonlinear functions of returns (e.g. absolute or squared returns) exhibit significant positive autocorrelation. In time-series of asset returns this can be seen as periods of higher volatility clustered together.

(g) **Slow decay of autocorrelation in absolute returns.** Autocorrelation function of absolute returns decays in time approximately as a power law.

(h) **Intermittency.** At any time scale, returns display a high degree of variability.

(i) **Leverage effect.** There is a negative correlation between the volatility of returns and returns themselves.

(j) **Volume/volatility correlation.** Trading volume is correlated with volatility measures.

(k) **Asymmetry in time scales.** Coarse-scale volatility measures predict fine-scale volatility measures better than the other way round. Cont [23] points out that those stylized facts should all be considered as mostly “qualitative properties”
of asset returns since they may not be precise enough to distinguish between different quantitative models (for example, many distributions can be used to fit heavy-tailed data). Nonetheless, even as qualitative, these properties can be quite constraining, since it is difficult to come up with stochastic processes or models that can produce a lot of them at the same time [23].

The existing artificial financial markets differ in the stylized facts they can reproduce, and the most commonly reported ones are heavy tails of return distributions, volatility clustering in time-series of returns and/or the occurrence of bubbles and crashes [63]. Some models are able to produce even more refined features, such as the power-law tails of the return distributions, thus concretizing the general notion of fat tails [98].

2.22 Summary

Prior to adopting an Agent based ASM Model to analyze the behavior of BSE, the characteristics of stock markets in general, and BSE in particular need to be studied. Hence, an insight into the dynamics of stock markets was given in this Chapter. In order to be able to determine the aspects that drive the dynamics, a microstructure based approach was applied. The possible route of orders in different market organizations was seen. In the first part of this chapter a list of aspects that are important to consider when studying market dynamics was proposed. Organizational factors and aspects related to price formation and traders’ behavior was discussed next. The former are mainly static and describe the structure of a market, the latter are mainly dynamic. In the second part of this chapter, approaches and theories about market dynamics was presented. Analytical models form the pillars of economic theory. They have been criticized however, on the simplifying assumptions made (such as investors’ homogeneous rational behavior, price formation at equilibrium). The advantage of these assumptions is that they lead to analytical tractability. In the latter part of this Chapter, the aspects of investor behavior were explored: overconfidence, sentiments (pessimism and optimism), self-attribution bias and loss aversion, regret, recency and primacy effects.
The structure and working of the BSE is given in Appendix A. BSE is an Order driven market. However, when compared to the developed markets of NYSE and NASDAQ, the major difference in the structure is that market makers are virtually non-existent in the BSE, notwithstanding the fact that provisions exist, as has been laid down by Securities and Exchange Board of India (SEBI).

Since the aim of the study is to see how market structure and traders’ behavior influence market dynamics, in the remainder of this thesis the focus is on agent-based approaches and consequently, on agent-based ASM.