Research Paper

Developing the Stock Pricing Model based on Bounded Rationality Theory

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ABSTRACT

The occurrence of unexpected and unpredictable phenomena in recent decades in financial markets around the world led to the development of theories and ideas beyond the defined principles and criteria of classic finance. These theories are based on financial psychology and they are explaining the role of psychology in financial sciences as an influential factor and became irreplaceable in financial markets and investor decisions. One of the important theories in this field is the bounded rationality theory, which can explain the behavior of decision-makers about financial and economic issues based on defined theoretical frameworks and assumptions. This study developed the stock pricing model by comparing the predicted stock price based on the bounded rationality theory and the real stock price by collecting and analyzing the initial information and data of 122 companies listed on the Tehran Stock Exchange during the period 2011 to 2019. The results of this study show the effectiveness of the bounded rationality theory based on the separation of stock return components and measuring the irrationality coefficient and emotional reactions of investors' decisions in stock prices. Accordingly, the limitations of investors 'ability to process information seem to affect the level of use of reasoning and rationality in decision-making and the effect of bounded rationality through the irrationality and limited attention on stock pricing. Therefore, it is expected that knowledge about the process of bounded rationality based on the rational bounded of investors and the behavioral biases resulting from the irrational part of their thinking, will provide a good explanation for the process of changes in financial markets. This can provide both profit opportunities and costs in investment management so that it can be used in modeling analysis and investment strategies.

1 Introduction

The development of financial markets has been accompanied by the entry and activity of different groups of investors and the greater complexity of these markets, so that everyone with the aim of achieving the highest level of return, has always sought to identify and analyze explanatory factors affecting the price of financial assets and obtain a correct insight related to the evaluation of the investment process. A review of financial markets around the world over the past decade, including Iran, shows

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that the market index has seen a wide range of fluctuations from rapid increases to rapid decreases over a long period of time. In a way that in different periods of time, a large number of investors have made partial purchases of stocks, which has led to market prosperity, high growth of the index, and increasing general market fluctuations and as a result, increasing the trend of emotional and irrational trading in the market. The occurrence of such events has seriously challenged the classic views and theories of capital markets and pricing about the existence of a rational approach between asset pricing in financial markets commensurate with predictable risks and cash flows and financial anomalies could not be explained well. With the entrance of psychological issues in financial markets which is named "behavioral finance", attention to sentiment in the process of investor decision-making in capital markets is defined as a systemic error or a kind of distrust in investors' rational attitudes [3]. This error especially in severe fluctuations and turbulences, whether rapid increases or decreases over a relatively short period of time have explained the trend of stock price changes and this is the justification for capital market anomalies. When investors buy stocks due to perceptions of inherent behavioral biases and the demand shifts induced by irrational speculation, an increase in emotional trading will lead to a boom in the market, ultimately leading to index high growth and increased overall market volatility [7]. Accordingly, a closer look at the reactions and behaviors of investors, as well as the movement of capital markets, shows that the decision-making process of individuals, contrary to what is shown in classic economic theories based solely on perfect information, perfect self-interest and perfect rationality which can be directly influenced by reactions, biases and behavioral biases in the market.

It is important to note that, although the presupposition of all investor behavior is clearly logical reasoning, for various reasons they are not able to process all the information available in the capital market and do not behave completely logically in their decisions. In such situations, they follow a kind of bounded rationality and show a combination of logical and irrational (emotional) behaviors. This issue was first raised by Herbert Simon [17], which suggests a cognitive approach to economic analysis and decision-making based on individual analysis of the conditions, constraints, and environment around the decision-making process, in which the decision-maker prefers his or her satisfaction to the ultimate desirability [15]. Thus, according to the bounded rationality theory, individuals in the decision-making process consider relative satisfaction and reduce the optimal decision to their desired decision as a strategy with reasons such as lack of sufficient opportunity to decide and think, access to large amounts of information or limited access to data and information for decision-making or insignificancy of cost-benefit of decision making. The manifestation of this approach in the capital market is when the price is affected by various factors and groups of variables, in which case investors often make decisions using available information, a process that certainly does not involve analyzing all relevant information. Therefore, it is expected that the pricing process in the capital market can be justified by relying on part of the logically classified information of investors and part of their sentimental and behavioral reactions, in line with market conditions. By developing the stock pricing model based on the effect of bounded rationality theory in the Tehran Stock Exchange, this study attempted to answer the question of whether the stock pricing model based on bounded rationality theory can predict stock prices. The present study can provide additional knowledge in the field of financial and behavioral principles in better understanding the role of different dimensions of constraints, beliefs, and sentimental and irrational reactions in financial decisions and quantifying its role in disproportionate reactions in Iranian financial markets and can improve performance of investors, analysts, and financial market policymakers. Therefore, explaining the decision-making structure of investors in terms of limited rationality can improve the performance of decision-making in purposeful behavior, which is a detailed description of the model of

purposeful behavior in limited rationality. In the next section, the literature review and prior research about bounded rationality and its role in investor decision-making and pricing are explained, followed by the theoretical foundations of the research hypothesis. Then, by explaining the research methodology and introducing the research variables, the results of the research hypothesis test are presented. In the final part, conclusions and suggestions from the research and suggestions for future studies are discussed.

2 Literature Review

Rationality in its simplest definition is a logical process for making a decision. Based on the assumptions formulated in the classical views of economics, human beings always act with completely rational behavior and consider all dimensions and information in the decision-making process with goals such as maximizing personal interests and desirability, but due to uncertainty in economic environments and the influence of various uncontrollable factors makes the realization of such an approach completely impossible [12]. Herbert Simon, referring to the logical presupposition of the nature of all human beings in the decision-making process, states that uncontrollable and sometimes controllable constraints or complexities in the decision-making process prevent individuals from making a perfectly rational decision [6]. Referring to the abstraction of some views of conventional rationality in classic economics, he considers the realization of all its assumptions only in an ideal environment and conditions of complete confidence. Bounded rationality is formed from the mental processing capacity, skills, and specialized business of individuals in problem-solving, access to information and involuntary environmental constraints, limited willingness in short-term choices instead of long-term benefits, lack of sufficient opportunity for decision making, individual or social tastes, preferences and values [16]. Therefore, based on the theoretical framework of bounded rationality, individuals are not completely ignorant or irrational in the decision-making process but have different levels and abilities of rationality due to the mentioned limitations. Accordingly, considering the fact that obtaining maximum benefits is one of the main pillars of rational decision-making, people also emphasize this issue and considering that removing restrictions, both environmental and individual, always requires effort, sufficient opportunity, and more cost, thus they consider optimization in decision-making, but inevitably base their decision on individual satisfaction [14].

As mentioned before, limited rationality is the approach taken in the decision-making process based on individual analysis of the conditions, constraints, and environment around the decision-making process, in which the decision-maker prefers his or her desirability and satisfaction to the ultimate desirability and optimization of the problem. Accordingly, the main strategy in finite rationality is to decide on the realization of relative satisfaction rather than ultimate desirability [5]. Due to the fact that the sense of satisfaction and desirability is different in various people, bounded rationality is considered a concept in the fields of behavioral economics and behavioral finance. The classification of bounded rationality in the field of behavioral finance is formed by relying on both normative and descriptive concepts so that it can accurately describe the norm as unwritten rules in financial and capital markets, which are mixed in practice with a level of awareness, habits, and feelings of individuals to provide plausible explanations for the type of behavior and reactions of investors and market trends [9].

Referring to the behavior of investors, bounded rationality is expected to be able to justify the irrational changes, jumps, increases, and decreases in price trends in the financial markets beyond the criteria defined by the classic views of the capital market. Considering the double importance and rapid impact of information in the financial and capital markets, it seems impossible for individual investors

to study the different dimensions of information in these markets in a short period of time. Therefore, it is expected that investors in the capital market, in order to adopt a strategy of buying, selling, or holding stocks or determining the value of stocks, first collect information based on their level of access and analysis ability, and then make decisions based on refined information. Since the limited attention of investors allows only a small amount of stock-related information to be accessed and examined against the high volume of information in the market, individual investors gave their limited level of knowledge, capabilities, or small calculations cannot analyze all dimensions of one event in the financial markets in a short period of time [1]. The process of financial and economic decision-making is always based on rational principles and frameworks, but due to the voluntary or involuntary constraints created in this process, individuals cannot solve thousands of issues simultaneously on a particular issue. Therefore, investors evaluate the costs of an incomplete decision (imperfect decision loss) against the benefits of savings on thinking costs (cost of rationality) and based on their limited attitude, taking into account their sense of satisfaction under the influence of inner feelings, their personal desirability which is chosen as a decision-making style to a certain degree of rationality [20].

In other words, in addition to logical analysis, investors face cognitive limitations in the use of reason and logic in the process of carrying out activities or making decisions based on unconscious feelings and actions. In such a situation, due to the fact that investors are not inherently risk-averse, they behave rationally based on the information obtained, but when the degree of information imperfection for them exceeds a certain threshold, they are somehow accompanied by a wave of behavior created in the market. In such a way that each group of investors will suffice with a part of stock information for analysis and decision making and will cause investors to make irrational decisions, which will be accompanied by over-reaction or under-reaction of investors in different stages of capital markets. It will upset equilibrium prices, create unusual phenomena, achieve abnormal returns in the market, and cast doubt on the rational efficiency approach of the market to explain all the information about an asset in price [13]. Accordingly, the existence of irrational reactions and investors' use of the bounded rationality approach in the selection and decision-making process leads to the equilibrium price deviation from its intrinsic values, thus it is expected that bounded rationality theory can explain the trend of price changes in the capital market.

3 Prior Studies and Research Hypothesis

Attention to stock pricing models has always been considered by researchers in finance and capital market studies, in order to gain a comprehensive understanding of the trend of stock price changes by examining the various dimensions affecting this process. In this section, due to the importance of stock pricing models, according to the central theme of this research, namely bounded rationality, the most relevant research has been reviewed, while there is little research on bounded rationality and its use in financial markets. Behavioral finance is an alternative model in finance that is based on fundamentally positive views of knowledge and reality. The beginning theoretical foundations of how to decide on the behavior of investors is formed in the paradigm of behavioral economics based on the theory of bonded rationality of Simon [17]. Simon et al. [18] believe that bounded rationality and the concept of "mostly logical, but only bounded" by criticizing the assumption of conventional rationality in the classic economics approach rejected complete knowledge and maximized optimization in the process of economic decision-making, and presented the reality of human behavior in economic life with respect to the existing limitations, based on the concepts of bounded rationality [18]. They point out that complete rationality is merely an abstract model and does not exist in real economic environments. Moreover,

computational system errors and different abilities of individuals in analyzing information make people face uncertainty, which limits the logical and rational decision-making process.

Kahneman [8] is one of the leading researchers in the field of psychology of decision-making and behavioral economics, who proposed the approach of cognitive psychology in the form of bounded rationality in the field of behavioral economics decision-making. By challenging the common assumption of human rationality in decision-making, he elaborates on the role of biases based on perceptions, emotions, discoveries, and intuitions in the process of economic decision-making, and by referring to the decision-making process in a way other than rational choice theories, he proposed that bounded rationality includes a combination of teachings, knowledge, perceptions, preferences, and judgments as the basis of many economic decisions [8]. Tseng [19] also by considering the efficient market hypothesis and key assumptions examined its shortcomings based on information and data from the Standard and Poor's Index, Dow Jones, and Nasdaq in the United States, and international survey of Japanese, Hong Kong, Singapore, Mexico, Taiwan and Canada market indexes from 1971 to 2005. Referring to the role of cognitive limitations and behavioral abilities of individuals in decision-making, he considered the use of the behavioral financial approach and bounded rationality theory in decision-making to be effective for investors to make better decisions in financial markets [19].

Gabaix [6] also points out that investor behavior is not always rational and not all information in the decision-making process is analyzed using classic financial models. He developed a model using investors' decision-making process based on bounded rationality theory and considering behavioral actions, cognitive limitations, and limited attention of individuals and updating the economic theory of consumer behavior according to the assumptions affecting the behavior of investors. The results showed that the Sparsity model can be used to explain the bounded rationality decision-making model based on the limited attention of individuals by simplifying criteria and factors in making decisions to avoid confusion and inattention and only important criteria are used as the basis for decision-making . Liang et al. [11] also presented a model for dynamic pricing of assets based on investors' inclinations, bounded rationality, and emotional reactions, referring to the Keynesian Beauty Contest. They extracted the model based on the theoretical foundations and the data collected from listed companies on the Shenzhen and Shanghai Stock Exchanges of China between 2014 and 2016 and showed the bounded rationality as well as the emotional reaction of investors have effect on the pricing process of the stock market so that the pricing process is affected and changed based on the trends and information and analysis that individuals have from the cumulative and accumulated market trend. This model also shows the intermittent effect of higher expectations of price fluctuations and the heterogeneous expectations of the emotional behaviors of inappropriate investors in financial markets. In another study, Liang et al. provided a framework for the simultaneous combined effect of investor constraints and their sentiments based on theories of bounded rationality and the reliance on price adjustment of assets on the Shanghai Stock Exchange. By presenting logical arguments and calculations with a deductive approach, they examined the extent to which price estimation information based on the bounded rationality model can be close to reality. The results show that the combined effect of two bounded rationality factors, which often include the losses of individual investors, is insensitive to market emotional reactions and leads to greater tolerance of estimated losses. At a higher level, investor rationality and stubborn market sentiment have led to increased demand and rising prices, while the different effects of bounded rationality factors are asymmetric. Figliolia et al. [5] also examined the role of bounded rationality in the use of accounting reports and the interaction between the quality of accounting reports and bounded rationality with the complexity of stock valuation in Brazil. Referring to the limitations of individuals' ability to

process information and decision-making and the desire to simplify the decision-making process, they suggested the use of bounded rationality as a new perspective to improve the decision-making process for stocks with hard-to-value stocks. They showed that if the stock valuation process is complex and hard, investors will rely more heavily on accounting reports to make decisions, taking into account the effect of information uncertainty, and react to behavioral biases such as overconfidence and limited attention and demonstrate directness in disclosing accounting information. Reviewing the literature shows the attention to bounded rationality in the field of behavioral finance in recent years, which has been part of the studies related to the capital market, so the study of new dimensions of this issue can provide a better understanding about the role of different dimensions constraints, beliefs, and limited logical and emotional responses to financial decision-making and quantifying its role in Iran's financial markets. Therefore, based on the conceptual framework and prior studies, the research hypothesis is expressed as follows:

Research Hypothesis: *The predicted stock price based on the bounded rationality theory model is significantly different from the actual stock price.*

4 Research Methodology

This study is behavioral research which in terms of purpose is applied research and it is based on quantitative methods. The research population includes all companies listed on the Tehran Stock Exchange in the period of 2011 to 2019, which have been selected based on the criteria considered below through the systematic elimination method.

1. The financial information and data of the company should be fully available during the research period.
2. The company has a continuous process of activity and the symbol of the company should not be closed for a period of more than three months in a year.
3. The selected company is a manufacturing company and is not one of the investment, insurance, and financial intermediation companies.
4. The financial year of the company should end in the March of each year and have not changed during the research period.

According to the mentioned criteria, 122 companies from 26 active industries are selected as a research sample.

Research Variables can be stated as follows: In order to test the research hypothesis, the research variables and their measuring method are explained below. In this study, the stock price is a dependent variable based on the theory of bounded rationality. To measure this variable, 5 main steps have been used which are described below.

Step 1: Calculate Stock Returns and Separate its Components in Terms of Bounded Rationality

In financial markets, pricing is based on investors' expectations of the asset's future prices and conditions for its advancement, as well as viewing the history of current price patterns and existing information. The most important dimension of valuation from the investors' point of view is the rate of return, which is considered the starting point of the rationally bounded pricing process in the market, which can be calculated based on equation (1) as follows [10].

$$R_{it} = \ln(D_{it} / P_{it-1}) \tag{1}$$

where:

R_{it} : Return on shares of the company i in period t.

D_{it} :Earnings per share of the company i in period t.

P_{it-1} :The stock price per share of the company i in period t-1.

To measure the bounded rationality of investors, earnings per share (D_{it}) are divided into three parts according to equation (2) [10].

$$D_{it} = d_{it} + S_{it} + v_{it} \tag{2}$$

where:

d_{it} : The excess return of company i in period t, which is calculated as described in equation (3).

S_{it} **:** The return due to the sentimental return of company i in period t, which is calculated as described in equation (5).

v_{it} : The default return of company i in period t, which is calculated as described in equation (6).

Excess returns (d) represent a portion of dividends and stock returns that are not considered in the initial calculations of the general investor and are usually perceived by those investors who have the ability to analyze information. One of the characteristics of this type of information is its access and difficult perception based on the rational behavior of investors, so it is expected that only rational investors will calculate it based on technical and fundamental analysis [10]. Excess return measured based on the difference between actual returns over a specified period of time (t) and expected stock returns can be performed as described in Equation (3).

$$d_{it} = R_{it} - \tilde{R}_{it} \tag{3}$$

Where:

R_{it} : The actual return per share of the company i in period t, which can be calculated and summarized based on the published historical information of the companies.

$\tilde{R}_{it}$:The expected rate of return per share of the company i in period t, can be calculated according to the five-factor model of Fama and French (2015) pricing of capital assets according to equation (4) [4].

$$(R_{it} - R_{ft}) = \alpha_i + \beta_1 (R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \varepsilon_{it} \tag{4}$$

where:

$(R_{it} - R_{ft})$:Risk premium and risks of stock returns of the company i in period t relative to the risk-free interest rate, (which is based on the interest rate of the normal short-term investment deposit of the country's banking network supervision policy package, approved by the Monetary and Credit Council each year) .

$(R_{mt} - R_{ft})$:Risk premium and risks of market returns according to the total market index, in contrast to interest-free risk.

SMB_t :The size factor (natural logarithm of stock market value), which is the difference between the stock returns of large companies and the stocks of small companies.

HML_t :The book value to market value factor which is the difference between stock returns with a high-value ratio to a low-value ratio.

RMW_t :Profitability factor (operating profit of the financial period to the book value of equity ratio), which is the difference between the stock returns of companies with high profitability and shares of companies with low profitability.

CMA_t :Investment factor (the change in the total assets at the end of the financial period to the total assets at the beginning of the financial period ratio), which is the difference between the stock returns of a company with high investment (bold) and the stock of companies with low investment (conservative).

First, the total shares of the sample companies are arranged based on market value, and then it is divided into two portfolios of large and small shares based on their medium. Then all companies are divided into three groups first (30%), middle (40%), and end (30%) by combining 2 in 3 with each of the risk factors and calculating the sensitivity of each risk factor by fitting the regression model and multiplying the factor yield and then summed up and the expected rate of return per share is determined. If investors are considered rational in the market, it is expected that there will be no sentimental reaction in the market or that the sentimental reaction will be offset by a large number of investors. In other words, when all rational investors make decisions and trade in the market without any tension, there will be no profit or return for sentimental and behavioral reactions in the market. The opposite of this situation is when investors' ability to analyze is limited, in which case their decision-making process will be accompanied by a sentimental response, and as a result, some part of the profits and stock returns in the market will be the result of such reactions [1]. To measure the profit from the sentimental response (S), market emotional indicators and criteria have been used as described in equation (5) [20].

$$S_{it} = \frac{\sum (R_{it} - \overline{R}_{it})(R_{itv} - \overline{R}_{itv})}{\sqrt{(\sum (R_{it} - \overline{R}_{it})^2 (R_{itv} - \overline{R}_{itv})^2}} \times 100 \tag{5}$$

where:

R_{it} :The rank of stock returns of the company i in month t in the selected sample size of the research.

R_{itv} :Rank of the historical volatility of company i in month t in the selected sample size of the research.

$\overline{R}_{it}$:The average rank of stock returns of the company i in month t in the selected sample size of the research.

$\overline{R}_{itv}$: The average rank of the historical volatility of company i in month t in the selected sample size of the research.

A key point about the calculations of equation (5) is that the stock returns and their volatility are ranked based on monthly information in the time domain of the research. For this purpose, based on the calculated monthly returns of the companies' stocks, they are ranked according to the stock returns of each company in each month (R_{it}), and then its volatility (R_{itv}) is calculated through the variance of the daily returns per share per month. Also, the calculations related to the average stock return rank ($\overline{R}_{it}$) and the average stock return volatility rating ($\overline{R}_{itv}$) are calculated based on the monthly information obtained for the entire time domain of the research. Default return (v) represents the portion of dividends that can be perceived by all investors and have an effect on the price. This information may be a collection of historical prices or disclosures of important recent company announcements that are usually visible with a small number and a high level of coverage. The default return of the current period

can be the basis for predicting future assumptions [11]. This component of dividends (D_{it}) can be calculated based on the difference between the other two parts - excess return (d_{it}) and return on a sentimental response (S_{it})- according to equation (6).

$$v_{it} = D_{it} - (d_{it} + S_{it}) \qquad (6)$$

Considering the division of dividend components into three parts, it is expected that when the trend of sentimental and irrational behaviors of investors in the market is less, the market will be less sensitive to the sentimental reaction of investors and as a result, the part of dividends that is related to sentimental response is to be ignored. Therefore, when investors make decisions with full access to information and in conditions of complete confidence and based on logical analysis techniques, no benefit will be generated from sentimental behaviors and earnings per share, followed by stock returns, only include default earnings based on routine information (v_{it}) and excess returns will result from fundamental market trend analysis (d_{it}) Accordingly, the stock return relationship (Equation 1) in terms of full access to information for investors will be described in equation (7).

$$R_{it} = \ln(D_{it} / P_{it-1}) = \ln D_{it} - \ln P_{it-1} = \left[(v_{it} + d_{it})\right] - \ln P_{it-1} \qquad (7)$$

If the access to information and awareness of investors is limited, the decision-making process will be different from when there is full access to information, because when investors cannot access acceptable information and explain situation based on rational reasoning, they will resort to sentimental and irrational reactions, and the market will be sensitive to behavioral reactions resulting from the bounded rational conditions of investors, thus investors will be faced with bounded rationality. In such a situation, due to the fact that each investor examines a piece of information, they act as logically as possible on the basis of the information obtained, and then, in some way, considering their level of personal desirability in decision-making, due to lack of sufficient logical information, they accompanied by an irrational wave created in the market. In this case, stock returns from the bounded rationality approach can be examined from two aspects of limited attention and sentimental response. Insufficient information and lack of full access to information, in addition to affecting the rational process of investors, lead to investors' irrational sentimental decision-making. Thus, the set of information for any investor in terms of bounded rationality will include limited logical attention and irrational sentimental response [11]. On the one hand, limited attention will cause investors to have access to only a limited amount of dividend information in the market, and on the other hand, investors, due to their low level of knowledge and ability to know or limited calculations, will be affected by external and unrelated factors (market sentimental reaction), which will affect stock returns [14]. According to the separation of the components of stock returns and the explanation of the subject of bounded rational investors, the stock return function can be defined as described in equation (8).

$$R_{it}^{BR} = \ln(D_{it}^{BR} / P_{i0}) = \ln D_{it}^{BR} - \ln P_{i0} = \left[v_{it} + \lambda_{it}^{BR}(d_{it}) + \tau_{it}^{BR}(S_{it})\right] - \ln P_{i0} \qquad (8)$$

where:

R_{it}^{BR} :Bounded rationality stock returns of the company i in period t.

D_{it}^{BR} :Bounded rationality earnings per share of the company i in period t.

P_{it-1} :The stock price per share of the company i in period t-1.

v_{it} :Default profit of company i in period t.

$\left[\lambda_{it}^{BR}(d_{it}) + \tau_{it}^{BR}(S_{it})\right]$:Bounded rationality of company i's investors in period t.

$\lambda_{it}^{BR}(d_{it})$:Bounded rational attention of company i's investors in period t.

$\tau_{it}^{BR}(S_{it})$:Sentimental reaction of company i's investors in period t.

Due to this fact that the set of information for any investor in bounded rationality situation includes a bounded attention ($\lambda_{it}^{BR}(d_{it})$) and their sentimental response ($\tau_{it}^{BR}(S_{it})$), by recalling the calculation of excess returns (d_{it}) based on the technical and fundamental capabilities of investors, if full access to information is impossible, investors will only have access to some of this information (bounded logical attention), thus in the case of bounded rationality, the excess return factor (d), i.e. (λ_{it}^{BR}) is between zero and one. Also, in such circumstances, investors' sentimental decisions will prevail over their rational approach, and as a result, the coefficient of return on a sentimental response (S_{it}), i.e. (τ_{it}^{BR}) will tend to one [11]. If the conditions of rationality are not limited to the decision-making process of investors, then the technical analysis of investors to achieve excess return (d) will be done completely and there will be no sentimental reaction in the market, in other words, the coefficient of excess return (d) i.e. (λ_{it}^{BR}) is equal to one and the coefficient of the sentimental reaction return (S_{it}), i.e. (τ_{it}^{BR}) will tend to zero. In such a situation, the stock returns will be equal to equation (7). In other words, equation (8) represents equation (7) that is, the return function of a rational investor, whose rational behavior is limited and whose decisions are influenced by sentiments. Therefore, the distinguishing feature of the return on investment in these two relationships (7 and 8) will be only the bounded rationality of investors [20]. Based on what has been stated, in accordance with the separation of different components of stock returns, to use the bounded rationality algorithm, the multi-criteria function of relation (8) is explained. Bounded rationality includes two main components of bounded logical attention and investors' sentimental response.

Step 2: The Bounded Rational Attention Function in Stock Returns

Since individuals cannot manage an issue at the same time in the decision-making process and the selection of unlimited dimensions, so in such a situation, people analyze stock returns according to some important criteria selected from their point of view to achieve excess returns [2]. Based on equation (2), it is possible to obtain more information for decision-making simply by analyzing information related to excess return (d), because default return information is normally understandable to all people and does not require to analyze. On the other hand, the return on sentimental response is not based on rational transactions and analyses based on rational decisions. Therefore, the only part related to the bounded logical consideration in decision-making will be the excess return on the stock (d_{it}). Recalling the conditions of complete uncertainty in decision-making and the limitations of the decision-making process, investors decide to use how much information of excess stock returns, which is known as the irrationality coefficient. The irrationality coefficient is the level of not using reason and logic in the process of doing things, activities, and actions or making decisions and choices, so that the lower the value, the higher the level of rationality and cognitive ability of the investor and as a result, investors' cognitive of stock analysis and stock return is more complete and will take fewer risks. Conversely, when the irrationality coefficient is higher, the level of rationality of investors is lower, and due to their

limited knowledge, the risk of their activity in the market will be higher [6]. Accordingly, investors will benefit from a relative return on stocks (percentage between zero and one hundred) depending on the volume of the information under review and the level of the irrationality coefficient [10]. Based on the discussion, the bounded logical attention can be calculated through equation (9).

$$\lambda_{it}^{BR} = \arg\min_{\lambda_{it}} \left[\frac{1}{2}(\lambda_{it}-1)^2 \sigma_{d_{it}}^2 + k_{it}|\lambda_{it}|\sigma_{d_{it}} \right] = \max\left(1 \pm \frac{k_{it}}{\sigma_{d_{it}}}, 0\right).\sin g(\lambda_{it})$$

$$\lambda_{it}^{BR} = 1 - \frac{k_{it}}{\sigma_{d_{it}}}$$

(9)

Where:

λ_{it}^{BR}: Bounded rational attention factor of the company i's investors in period t.

k_{it}: The irrationality coefficient of the company i in period t.

$\sigma_{d_{it}}$: Monthly standard deviation of excess stock return of company i in period t.

According to equation (9), investor irrationality includes overreaction, disposition effect, and under-diversification, which are more common in minority investors. Because typically, minority investors make unwise and uninformed decisions. This is mostly due to irrational behavioral biases, of which overconfidence is one of the main reasons [21]. Therefore, it is expected that there is a relationship between the irrationality coefficient and institutional shareholders so that the more stock ownership is owned by institutional shareholders and the more stocks are traded by them, the less investor irrationality is about those stocks [6]. According to the above explanations, the churn rate is used to determine the coefficient of investors' irrationality. The churn rate is a negative symbol for the degree of investor irrationality in stock selection. For this purpose, the rate of institutional shareholders fall of each company in monthly sections is calculated by equation (10).

$$CR_{it} = \frac{\sum_{i \in Q} |(N_{it} \times P_{it}) - (N_{it-1} \times P_{it-1}) - (N_{it-1} \times \Delta P_{it})|}{\sum_{i \in Q} \frac{|(N_{it} \times P_{it}) - (N_{it-1} \times P_{it-1})|}{2}}$$

(10)

where:

CR_{it}: The rate of institutional shareholders fall of company i in period t.

N_{it}: Number of institutional shareholders stocks in the company i (any shareholder who owns more than 5% of the company's stocks) in period t.

P_{it}: The stock price of company i in period t.

N_{it-1}: Number of institutional shareholders stocks in the company i in t-1 period.

P_{it-1}: The stock price of the company i in period t-1.

ΔP_{it}: Changes in the stock price of the company i in period t (first period compared to the end of the period).

Q: The sum of sample-size companies that have shareholders or institutional investors.

Due to this fact that the basis for calculating the irrationality coefficient is the shareholder fall rate,

then with the calculated value of the institutional shareholder fall rate (CR) by equation (10), the irrationality coefficient is calculated by equation (11).

$$K_{it} = V_{it}^{-1} \left(\frac{1}{12} \sum_{r=1}^{12} CR_{it} \right) \qquad (11)$$

where:

V_{it} : Percentage of shares owned by institutional shareholders of the company i in period t.

Typically, in a situation where the composition of investors includes institutional investors and they own a big part of shares, the level of rationality in the decision-making process will be higher and the irrationality coefficient (k_{it}) will be lower and there will be less demand sensitivity for the irrationality coefficient. Conversely, when the majority of shareholders are minority investors and retailers, the level of rationality is lower, and the irrationality coefficient (k_{it}) will be higher and they have higher sensitivity demand for the irrationality coefficient; So that the range of their sentimental response threshold will be larger and the amount of adjusted sentimental response outside the threshold will be smaller [6].

Step 3: Investors' Sentimental Response Function in Stock Returns

According to the explained relationship between stock returns and the separation of its various components (equation 8), for using the bounded rationality algorithm, the two main components of bounded logical attention and the sentimental response of investors can be examined. In a situation where investors are limited in their access to information and its logical analysis (either by force or voluntarily), part of the decision-making process is based on sentimental behaviors. This trend intensifies when logical relationships have fewer role in the decision-making process. The justification for these conditions will be a kind of savings in the costs of thinking (the cost of rationality) based on limited attitudes [20]. In this regard, the optimization of sentimental response is based on the logical argument of incomplete decision costs and thinking costs which can be explained by equation (12).

$$\tau_{it}^{BR} = \arg \min_{S} \left[\frac{1}{2} (S_{it} - \mu_{it})^2 \sigma_{s_{it}}^2 + k_{it} |S_{it}|^{\phi} \sigma_{s_{it}} \right] \qquad (12)$$

where:

$\frac{1}{2}(S_{it} - \mu_{it})^2 \sigma_{s_{it}}^2$: Loss resulting from an incomplete decision.

$k_{it} |S_{it}|^{\phi} \sigma_{s_{it}}$: The cost of a reasonable decision and the use of rationality.

According to equation (12), when the loss of an incomplete decision is reduced, the level of bounded rationality of the investor will increase, which will lead to a simultaneous increase in the cost of rationality. In other words, when the first statement (loss due to an incomplete decision) decreases, the second statement (the cost of using rationality) will increase by the same level. Based on this argument, by considering the explained logical argument, the coefficient of the sentimental reaction of investors can be calculated. In fact, the function of recognizing sentimental response in the range ($S_{it} \in (-k_{it}/\sigma_{s_{it}}, k_{it}/\sigma_{s_{it}})$) can be changed, so that the sentimental response is a value set in line with the return on the sentimental response with the bounded rationality of the investor in the range)($\pm k_{it}/\sigma_{s_{it}}$, indicating overreaction or under reactivity. Accordingly, the hypothesized states for the coefficient of sentimental response function recognition (τ_{it}^{BR}) can be explained by Fig. 1 [10]:

If $k_{it}=0$ and $\tau_{it}^{BR}(S_{it})=\mu_{s_{it}}$, the investor has a relatively high level of rationality and makes decisions based on a review of all important and effective aspects.

If $k_{it} \rightarrow \pm \dfrac{\mu_{s_{it}}}{\sigma_{s_{it}}}$ and $\tau_{it}^{BR}(S_{it}) \approx 0$, the investor makes decisions based on the rule of thumb, by simplifying the issue and considering the components that are understandable and can be easily analyzed.

If $0 \langle \left| k_{it} \right| \pm \dfrac{\mu_{s_{it}}}{\sigma_{s_{it}}}$ and $\tau_{it}^{BR}(S_{it}) \in (0, \mu_{s_{it}})$, in this case the investor makes decisions based on the conditions of bounded rationality.

Fig.1: Coefficient of Investors' Emotional Response Function

Step 4: Optimal Model of Return on Investment in Conditions of Bounded Rationality

Investors typically invest in a variety of assets to reduce risk, they generally invest a part of their wealth in high-risk assets (α) and the other part in risk-free assets ($1-\alpha$). Therefore, the return on their investment is also a function of the return on high-risk assets investment and risk-free assets investment. Therefore, the optimal return on investment model of individuals is based on the stock return model with components separated in logical terms (equation 7) which is in the form of equation (13) [10].

$$R_{p_t}=R_{it}\,\alpha_t+R_{f_t}\,(1-\alpha_t) \tag{13}$$

where:

R_{p_i} :Return on investment portfolio in reasonable condition and without any restrictions in period t.

R_{it} :Return on stocks in reasonable terms in period t (equation 8).

R_{f_t} :Return on assets without risk in period t.

α_t :Allocated share of investors' wealth in high-risk assets in period t.

$(1-\alpha_t)$:Allocated share of investors' wealth in risk-free assets in period t.

Similarly, the optimal model of return on investment in terms of bounded rationality can be explained as equation (14) by considering the model of stock returns in terms of bounded rationality (equation 8) based on the allocation of capital to high-risk assets (α) and risk-free assets ($1-\alpha$). [10].

$$R_{p_t}^{BR}=R_{it}^{BR}\,\alpha_t+R_{f_t}\,(1-\alpha_t) \tag{14}$$

where:

$R_{p_i}^{BR}$:Return on investment portfolio in terms of bounded rationality in period t.

R_{it}^{BR} :Returns of bounded rationality shares of the company i in period t (equation 9).

R_{f_t} :Return on assets without risk in period t.

α_t :Allocated share of investors' wealth in high-risk assets in period t.

$(1-\alpha_t)$:Allocated share of investors' wealth in risk-free assets in period t.

The calculation of the allocated share of investors' wealth in high-risk assets (α) under conditions of bounded rationality is based on the condition of limited attention to excess stock returns and sentimental returns in the market, which will be related to the irrationality coefficient and its changes. Thus, the lower the irrationality coefficient, the higher the level of investor rationality and the higher his cognitive abilities. Conversely, when the irrationality coefficient is high, the investor's rationality level will be lower and their knowledge of excess returns and sentimental stock returns will be more limited. As a result, wealth allocation for risk-free assets increases, and the share allocated to high-risk assets decreases proportionally [10]. Therefore, considering the model of optimal return on investment in terms of bounded rationality (equation 14), equation (15) has been used to calculate the allocated share of investors' wealth in high-risk assets (α).

$$\alpha_t = \frac{R_t^{BR} - R_{f_t} + \frac{1}{2}\sigma_{d_{it}}^2}{\sigma_{d_{it}}^2} = \frac{(1-\lambda_{it}^{BR})(d_{it})}{\sigma_{d_{it}}^2} + \frac{\tau_{it}^{BR}(S_{it})}{\sigma_{S_{it}}^2} \qquad (15)$$

Step 5: Stock Price Forecasting Model Based on Bounded Rationality Theory

It is normally expected that the equilibrium price (P_{it}^*) to be determined depending on all aggregate demand and supply of high-risk assets and the market clearing process. In a way, if the demand in the market exceeds the supply level, the price of assets will increase, and vice versa, the decrease in demand relative to supply will lead to a decrease in the price of assets, and this process will continue to balance new points. Thus in equilibrium price, supply and demand for high-risk assets will be equal [21]. Based on the above discussion, investors' limited access to information is expected to lead to more sentimental reactions due to reduced transparency. In other words, in such conditions, increasing the level of limited attention of investors leads to a decrease in the estimate of core value and the decision-making process of investors is out of the normal routine and sentiments overwhelm the logical aspects of investors' decision-making. In this process, the hopeful and optimistic sentimental reaction of investors leads to a positive deviation from the previous equilibrium price, and the disappointing and pessimistic sentimental reaction of investors leads to a negative deviation [20]. In this regard, using the defined model of stock returns in accordance with the components separated in terms of bounded rationality (equation 8) and the optimal model of return on investment in terms of bounded rationality (equation 14) based on the exponential function, stock pricing model as described in relation (16) has been shown.

Equation (16) shows that the equilibrium price can be decomposed into two parts: the condition of logic ($P_{it}^R = e^{(v_{it}+d_{it}-R_f-\frac{1}{2}\sigma_{d_{it}}^2)}$) and the condition of bounded rationality (($P_{it}^{BR} = P_{it}^R \left(e^{\left[(\lambda_{it}^{BR}-1)\,d_{it}+\tau_{it}^{BR}(S_{it})\right]}-1\right)$).

The bounded rationality condition includes: the limited cognition (attention) part of the extra dividend ($P_{it}^R \cdot \exp\left[(\lambda_{it}^{BR}-1)\,d_{it}\right]$) and the investors' sentimental reaction part ($P_{it}^R \cdot \exp\left[\tau_{it}^{BR}(S_{it})\right]$) which will form the bounded rationality condition due to the combined effect of the investors' bounded cognition and the market sentimental reaction.

$$\begin{aligned}
P_{it}^{*} &= \exp[\ln D_{it}^{BR} - R_{f_t} - \frac{1}{2}\sigma_{d_{it}}^2] \qquad (16)\\
&= \exp\left\{(\ln D_{it}^{BR} - \ln D_{it}) + [\ln D_{it}^{BR}] - R_{f_t} - \frac{1}{2}\sigma_{d_{it}}^2]\right\}\\
&= \exp\left\{[(\lambda_{it}^{BR}-1)\times d_{it} + \tau_{it}^{BR}(S_{it})] + [\nu_t + d_{it} - R_f - \frac{1}{2}\sigma_{d_{it}}^2]\right\}\\
&= e^{[\ln(D_{it})-R_{f_t}-\frac{1}{2}\sigma_{d_{it}}^2]} \times e^{(\ln D_{it}^{BR}-\ln D_{it})}\\
&= e^{(\nu_{it}+d_{it}-R_{f_t}-\frac{1}{2}\sigma_{d_{it}}^2)} \times e^{[(\lambda_{it}^{BR}-1)\,d_{it}+\tau_{it}^{BR}(S_{it})]}\\
&= P_{it}^{R} + P_{it}^{R}\left(e^{[(\lambda_{it}^{BR}-1)\,d_{it}+\tau_{it}^{BR}(S_{it})]}-1\right)\\
P_{it}^{*} &= P_{it}^{R} + P_{it}^{BR}
\end{aligned}$$

The presence of a sentimental market reaction leads to cognitive bias. Therefore, according to the explained theoretical foundations, the description of the steps related to the calculation of stock prices based on the theory of rationality, and the conceptual framework of the research are described in Fig.2.
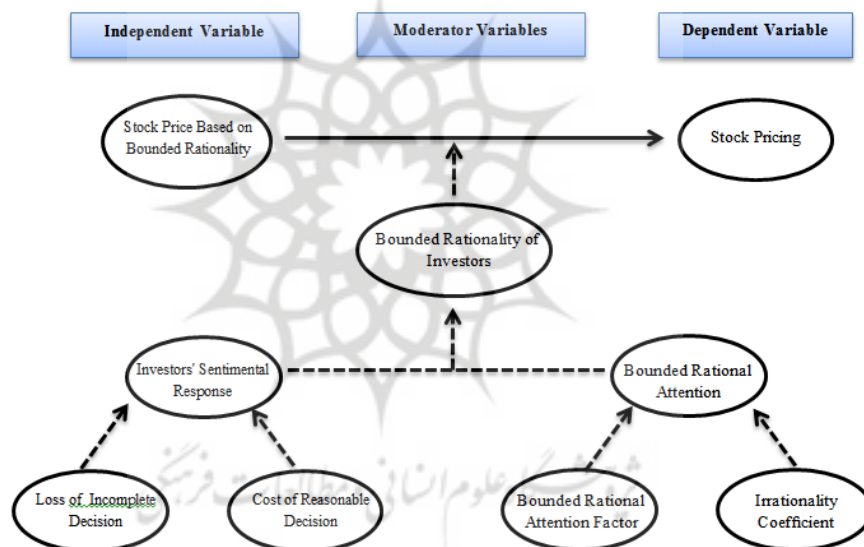

Fig.2: Research Conceptual Framework

5 Research Results

This section incorporates Research Results. This section incorporates only final conclusions concerning all variables. In order to evaluate the research results, first the descriptive statistics of the real values of stock price (P_{it}) and the price obtained from the bounded rationality theory (P_{it}^{*}) in Table 1 have been studied. According to the results of Table 1, the Mean real value of the stock price is 5,849.001 with a standard deviation 6,736.433 and the Mean price obtained from the bounded rationality theory is 5,837.002 with a standard deviation 6,415.648.

Table 1: Descriptive Statistics of Research

Variable	Mean	Median	Maximum	Minimum	Standard deviation	Skewness	Kurtosis
P_{it}	5,849.001	5,849.734	71,205.00	394.00	6,736.433	0.002	0.018-
P_{it}^{*}	5,837.002	5,836.301	88,856.17	355.75	6,415.648	0.000	0.017-

In order to ensure results and interpret the output as a meaningful statistical quantity, the default tests are reviewed, including normality and unit root test (Im, Pesaran, and Shin W-Stat) are examined. Table 2 shows the results of the normality test of research variables by using Kolmogorov-Smirnov statistics, that the research variables have a normal distribution. in this test, the null hypothesis (H_0) states that the population is normally distributed, against the alternative hypothesis (H_1) that it is not normally distributed. If the test (Sig.) is less than the predefined significance level, can reject the null hypothesis (H_0) and conclude the data are not from a population with a normal distribution. If the (Sig.) is greater than the predefined significance level, cannot reject the null hypothesis (H_0).

Table 2: Normality Test

Variable	Kolmogorov-Smirnov Statistic	Sig.
P_{it}	0.001	0.200
P_{it}^{*}	0.000	0.198

Table 3 shows the results of the durability test of research variables. Based on the unit root test by using the Im, Pesaran, and Shin W-stat methods, the durability of both variables is acceptable. The null hypothesis (H0) is generally defined as the presence of a unit root (process has unit root) and the alternative hypothesis (H1) is defined as the trend stationarity (Process has no unit root). The test statistic real values of stock price are -9.656 and the test statistic price obtained from the bounded rationality theory is -9.672. Since both test statistic is lower than all of the critical values, can reject the null hypothesis (H_0).

Table 3: Unit Root Test (Method: Im, Pesaran and Shin W-stat)

Variable		Statistic	Sig.
P_{it}		-9.656	0.000
P_{it}^{*}		-9.672	0.000
Test critical values:	1% level		-3.959
	5% level		-3.410
	10% level		-3.127

In order to test the research hypothesis and to compare the predicted stock price based on the theory of bounded rationality and the real stock price on the Tehran Stock Exchange, the stock pricing model is developed based on the theory of bounded rationality and according to the steps described. The research hypothesis points out that the predicted stock price based on the theory of bounded rationality is significantly different from the actual stock price. For this purpose, the

real values of stock price (P_{it}) and the price obtained from the bounded rationality theory (P_{it}^{*}) model are compared using the means comparison test. Since the two groups of variables are

compared to determine the presence or absence of significant differences between these groups, the means comparison test is used. In a comparative analysis of means, the t-test is used for the significance or non-significance of the model. Accordingly, the null hypothesis of this test (H_0) indicates that the research hypothesis is not rejected and there is a significant difference between the mean of the estimated price based on the model of bounded rationality theory and the real price and the alternative hypothesis (H_1) indicates the rejection of the research hypothesis. The results of testing the research hypothesis using the mean comparison test are represented in Table 4.

Table 4: Results of Testing the Research Hypothesis

Index	Test value = 0					
	t-statistic	Df	Sig. t	Mean diff.	95% confidence level	
					Low level	High level
Bounded rationality pricing model	1.513	11505	0.130	3.436	-1.016	7.889

Table 4 shows that the significance level of the test is 0.13, which is greater than the error level of the test, which is greater than 0.05, so with a five percent error, the null hypothesis that there is no significant difference is not rejected and the average score of the first hypothesis has no significant difference with zero, of course, this inference is also possible due to the negative value of the low level and the positive value of the high level of the confidence interval.

6 Conclusion and Suggestions

Examining the general trend of changes in financial markets shows that many changes cannot be explained using classic financial theories. In other words, traditional asset pricing models often assume unlimited ability for investors in the decision-making and trading process. Absolutely in such a situation, desirability is defined by achieving the goal, but by considering the relative attention, bounded cognition ability, and cost of access to information in the decision-making process, investors show the combination of logical and irrational behaviors according to the limitations of the decision-making process and based on bounded rationality theory. With regard to this issue, this study aims to explain the stock pricing model based on the theory of bounded rationality by collecting information and financial data of 122 companies listed on the Tehran Stock Exchange over a period of 9 years between 2011 to 2019. Based on the research hypothesis, there is no significant difference between the predicted stock price based on the bounded rationality theory model and the real stock price and this hypothesis is tested using the means comparison test. The results of the study indicate that the research hypothesis is not rejected, which indicates the effectiveness of the theory of bounded rationality based on the separation of stock return components and measuring the irrationality coefficient and sentimental reactions of investors' decisions on stock prices and this result is consistent with Liang et al. (2017).

Accordingly, in a general conclusion, it seems that the limitations of investors 'ability to process information and predictability of the unknown future affect the level of use of reasoning and rationality in decision making and bounded rationality affects stock pricing through investors' irrationality and bounded attention. When an investor makes a decision based on bounded rationality, he selectively processes the available information and data, increasing the effects of irrational actions and emotional

reactions on judgment and decision, thus making his market behavior more fragile. He also is influenced by positive or negative cognitive biases to stimulate stock demand beyond rational market demand and determine stock price changes. Due to the separation of the various components of stock returns, in the context of bounded rationality, the investor's knowledge of additional profits is more limited, which can reduce or increase the sentimental recognition demand for supply or stock demand. Thus, irrational reactions can lead to a positive deviation from the equilibrium price based on fundamental value, and pessimistic irrational reactions can lead to a negative deviation from the intrinsic value of financial assets and stocks. Thus, increasing the level of irrational or sentimental reactions of investors will be accompanied by more restrictions on rationality, which optimistic sentimental actions, rapid increase in prices and vice versa, limited level of rationality in investors and declining sentimental reactions of the market together lead to a rapid decrease in prices. Therefore, the bounded rationality approach can be used as a relatively new perspective in financial and capital markets to explain and analyze the trend of changes in these markets, which justifies the various dimensions of the investor decision-making process. Therefore, considering the approach between economic human and purely sentimental and irrational actions, investors' behavior is seen as a mixture of logical relationships and sentimental reactions. Although they start with a very rational motivation in the decision-making process, the costs associated with rational choice and the ability to process quickly and complete information in the decision-making process by disregarding the best possible decision in covering non-professional market players and incomplete use of available information, they associate part of the decision-making process with sentimental and irrational behaviors and make decisions based on their satisfaction with the pricing of stocks or the purchase, sale or holding of stocks in the financial and capital markets. Accordingly, it is expected that in practice, awareness of bounded rationality based on rational constraints of investors and behavioral biases resulting from the irrational part of their thinking will provide a good explanation for the changing trends of financial markets that can provide both opportunities and costs in investment management. Therefore, considering the importance of the level of rationality of investors for the development of theories and models in finance, it is suggested to use the theory of bounded rationality in practice and be aware of the rational limitations of investors and behavioral biases due to their irrational thinking. These results provide insights about changes in financial markets that due to the biases and dual decisions of the cognitive-sentimental process, create both profit opportunities and costs in investment management so that it can be used in modeling, analysis, and investment strategies.

One of the limitations of this research is the lack of studies on bounded rationality in the field of finance and capital markets. As discussed in the research background, empirical research on bounded rationality in the financial field is in the early stages which Limited the access of researchers to bounded rationality literature in financial markets and it will certainly be effective in the process of developing theoretical foundations and even how to measure it. Also, the limitation in collecting the initial data of the research due to the lack of information of some companies and the increase of missing data has led to a decrease in the sample size. The occurrence of some non-financial and non-economic events in the study period, including some specific political or social issues, unintended changes in preferences, type of behavior, and risk of investors and activists in the Iranian capital market affected the research results that these changes are beyond the control of the researcher.

For future studies, it is suggested to explain stock pricing in financial and capital markets from different dimensions using different theories and examining theories of other sciences in the analysis of stock market trends, including humanities, psychology, or even engineering from a bounded rationality

approach in the field of finance and accounting. For example, researchers can pay attention to the role of accounting information and reports or pay attention to the role of investor education and experience as a moderator variable in determining the value of stocks in the bounded rationality approach, reviewing capital budgeting and corporate financing. Future research can also emphasize the role of bounded rationality in relevant decisions and explain the dimensions of conservatism in accounting based on bounded rationality theory.

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