An Analysis of Investment decision through Neurofinance Approach

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The present paper analyses Investment decisions of individuals through the neurofinance approach. Neurofinance is a very young discipline in Behavioural finance. The authors review the factors influencing investment decisions, which involve neural processes. The authors have made contextual analysis to throw light on the link between decisions and the behaviour of the brain. This contextual analysis has greater implications on exploring and researching brain nerves and their influences for psychological biases. Neurofinance has become an effective tool for efficient economic decision-making through brain mapping techniques. This study further discusses the interaction between behavioural psychology, neurosciences, economic, and investment decision making. This paper largely depends on secondary information, and available research literature for making contextual analysis. It is hoped that this paper would form the basis for further empirical research to analyse investment decisions of individual investors with a focus on Neurofinance constructs.

Keywords: Efficient market Hypothesis, Behaviour Finance, Neuro Finance, Metacognitive Thinking

1. Introduction

The most accepted neoclassical assumption on investment objective is 'maximisation of return and/or growth'. However, Behavioural Finance believes that the investment objective depends on the investors' behaviour. Behavioural Finance examines the neoclassical utilitarian assumption and believes that human behaviour persistently violates, and considers alternative explanations for investment objectives. Application of Behavioural Economics tenets to investment risk is Behavioural Finance that investigates how people act and respond to the process of making financial decisions, and analyses these actions as per psychological concepts and theories. In contrast, neurofinance proposes to identify and analyse the black box of the human brain to understand the physiological developments (including hormonal activities) that take place when people make financial decisions.

Approaches of regular investors and researchers are quite different in many aspects. Technical analysis, which is varying with Efficient Market Hypothesis (EMH), has played an important role for most of the investors in making their financial decisions. EMH and Behavioural Finance proponents different debate on the extent or degree of market efficiency, investors rationality, and many empirical findings. EMH assumes that market participants are perfectly rational in valuing securities, while with irrational investors, their trading activities will either cancel out or will be arbitraged away by rational investors. Finally, market participants have well defined subjective utility functions.

The efficient market theory has not still correlated the stock market fluctuations with the fundamental principles. It seems that behavioral finance can explain market exceptions. Neurofinance foresees to go beyond behavioral finance, as it promises to identify the psychological causes underlying deviations from neoclassical utility-maximizing behavior.

Comparison between Traditional, Behavioural and Neuro Finance
This study highlights the implication of neurofinance with respect to the Efficient Markets Hypothesis. The purpose of this study to provide further steps to analysis the behaviour and Neuro finance concept in wider range.

Theoretical Frame Work
Correlation between the Neurology and the Individual Investment Patterns of Buyers
Our brain reacts in expectation of a possible reward where human brain and behaviour not balances and matched with the conventional theory of finance. As per social status and its environment, individual investors can behave and duplicate their feelings and emotions from every other person which may in turn the financial decision-making as well amplify the choice of such decisions. Human behavior is partly the outcome of a fluid interaction between controlled and automatic processes. Neoclassical approach frequently and deceptively construes many behaviours with the product of cognitive deliberation alone. Since for efficiency automatic processes must keep behavior “off-line” and below consciousness, human beings have far more introspective access to controlled than to automatic processes.

According to Neurofinance, the Human Brain is Categorized into Three Main Parts.

<table>
<thead>
<tr>
<th>Parts of Human Brain</th>
<th>Forebrain/ Cerebrum</th>
<th>Mid-brain</th>
<th>Hind-brain/ Little Brain</th>
</tr>
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<tbody>
<tr>
<td>Largest and rational part of</td>
<td>largest and rational part of the brain consisting of the cortex and the</td>
<td>It takes cares the mental picture, all senses and body movement</td>
<td>It is vital bodily</td>
</tr>
<tr>
<td>the brain</td>
<td>limbic system, which helps in taking financial decisions.</td>
<td></td>
<td>processes.</td>
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Technologies to Map the Brain
What will be taken upon the demanding task of brain mapping? As Lichtman says “To know our brains in detail and a lot of our thinking about the brain is based on imperfect awareness of what is actually there”. To understand the brain’s structure and function, Scientists and researchers uses various technologies. Connectomics method allows researchers to see all the connections between neurons in an intact brain.

2. Literature Review
Kuhnen and Knutson, who initiated the developments in the field of neurofinance study by using brain. In their study they contemporary the function of human brain sentiments in financial decision making. Further they assessed the brain imaging studies analysis that affect suggest by the expectation of achieve and defeat may bear distinct neural signatures.

This concept was accentuated by the Lo et al in their study every financial decision made by the individual investors were influenced by their sentimental functions. They further studied that the individual investors respond to both financial gains and losses that give forces are part of limbic system of the brain conduct the individual’s decision under fear and uncertainty. Morse in his study he referred that the more vigorous the primeval, risk-forecasting brain area, the more risk reluctant the individual investors are. Furthermore, from Inside the Investor’s Brain the Power of Mind over Money Peterson presents the two neurotransmitters namely dopamine and anterior insular. The dopamine (also called the delight element of the brain) which is linked with craving and serotonin which is linked with shyness. The anterior insular is linked with expressive experience and mindful thoughts, which includes feelings of hurt, rage, pleasure, repulsion, terror and irritation.

The sentiments and testosterone of the human brain how it linked with risk-taking and gambling that “high-testosterone investors have a higher craving for monetary risk-taking and are more probable to surrender to definite impulsivity-related pathologies”.

Objectives
• The relation between neurofinance and investment decision of the investors.
To understand the Metacognitive Thinking and investors’ expectations on financial decision making.

Two-dimensional characterization of neural functioning

Controlled processes\(^3\) tend to be serial, (very calculative), tend to be invoked deliberately by the individual investors decision-making encounters a challenge or surprise are often associated with a subjective feeling of effort. This controlled processing is conscious the investors mostly have the logical reasoning for their investments. The investors or the financial market advisors may use the strategic financial decision-making tools such as decision trees, dynamic analysis and financial analytical methods.

Automatic processes\(^4\) are processes which flow in the opposite direction of controlled processes. The functioning dimensions of automatic processes are they operate in parallel, are not associated with any subjective feeling of effort, and operate outside of conscious awareness. As a result, most of the investors often have unexpectedly slight introspective access to why automatic choices or judgments were made. It’s only later that the controlled system reflects on the judgment and tries to substantiate it logically\(^\text{xii}\).

Cognitive automatic processes activity concentrated in the back (occipital), top (parietal) and side (temporal) parts of the brain. The amygdala is responsible for many important automatic affective responses. Controlled processes occur mainly in the front (orbital and prefrontal) parts of the brain. The prefrontal cortex (pFC) is sometimes called the “executive” region, because it draws inputs from almost all other regions, integrates them to form near and long-term goals, and plans actions that take these goals into account\(^\text{xiii}\). The prefrontal area is the region that has grown the most in the course of human evolution and which, therefore, most sharply differentiates us from our closest primate relatives\(^\text{xiii}\). Controlled processes occur at expected moments when automatic processes become ‘interrupted’, which happens when a person encounters unexpected events, experiences strong intuitive states, or is presented with some kind of obvious challenge in the form of decision\(^\text{xiv}\).

This Automatic and Controlled processes can be defined into Cognitive and Affective with four Quadrants. 

**Quadrant I** is in charge when individual investor deliberates whether to take long term financial decisions such as investment in real estate over present-value calculations; 

**Quadrant II** is used by “method actors” who envisage previous emotional experiences to fool audiences into thinking they are experiencing those emotions; 

**Quadrant III** governs the movement of your hand as you return serve; and 

**Quadrant IV** makes you react when somebody says “Wow!”

When the brain challenges a new decision, it initially draws heavily on varied regions of itself, including the prefrontal cortex (where controlled processes are concentrated). Over a period, the response to that decision becomes more rationalized and rigorous in brain that are specialized in processing the relevant tasks.

Metacognitive Thinking and Investors’ Expectations

The implication of Metacognitive thinking with respect to the investors’ expectations from the perspective of efficient markets hypothesis. Neuroscience indicates us that thinking executes serious process of stress and strain on the mind causes thinking turn into Metacognitive thinking which in turn time consuming and expensive. Cognition requires concentration. When thinking is costly, decision-making is costly. Individuals compare the costs and benefits of thinking about a decision-making. That individual investor does not apply their thinking capacity fully, and therefore their decisions deviate from which are assumed by the efficient markets hypothesis\(^\text{xv}\). Financial economists believe that the Price Mechanism is the most effective way to aggregate information. However, when thinking is expensive the individual do not attain optimal (costless) outcomes, and market prices do not replicate all relevant information; the financial market outcome deviates on the efficient markets hypothesis.

Constructive Framework for Metacognitive Thinking and Investors’ Expectations

Decision-making is expensive due to the time and money invested for gathering information and it takes extensive thinking to determine an optimal. The thinking cost brings to the fore the trade-offs between the quality and the cost of the decision\(^\text{xvi}\).
Problem Formulation
We consider the thinking trials as a sequence of independent and identically distributed random variables. During going to the population mean of the return from the individual investors we collect the statistics estimation of a population parameter.

In this process a larger sample of our observation are used, and the statistics is derived from the usual process of parameter estimation. The sequence of random variables indexed by time is called stochastics process in which time can be discrete or continuous. The values taken by the random variables may be discrete or continuous.

We are let to consider a process which is indexed continuous in time and value of neurofinance metacognitive process.

Law of Large Numbers and Central Limits Theorem
The sample mean converges to population mean in probability for large sample is known as Law of large numbers.

The quotient of the difference between sample mean and population mean divided by standard deviation of the population and square root of sample size converges in distribution to standard normal variate. This is known as central limit theorem in probability.

Unbiased Estimator
A statistic is said to be an unbiased estimator of a given parameter when the mean of the sampling distribution of that statistic can be shown to be equal to the parameter being estimated.

Minimum Variance Unbiased Estimator
Statistics a minimum-variance unbiased estimator (MVUE) or uniformly minimum-variance unbiased estimator (UMVUE) is an unbiased estimator that has lower variance than any other unbiased estimator for all possible values of the parameter.

Axiomatic process of the brain subject to a sequence of uncertain moments. This has to convergence in the decision in thinking sequence of trials. We postulate these sequences of independent and identically distributed random variables. Such sequence is studied in probability theory through the concept of central limit theorem.

Here we define convergence in expectations to agree with concept of Expected Market Analysis and Neurofinance decisions. Since investor are not using to infer automatic process, the controlled system may reflect on the judgement and attempts substitute logically but often does spuriously.

When the investor spends more on Metacognitive thinking cost to the formation of an accurate expectation, investor will suffer a different loss.

\[ (q(T) - P)^2 + MT \] \quad Eq. (1)

where

P is denoting the logarithm of the next period's asset price
q(T) is the investors' expectations of P
MT is Metacognitive thinking cost
T is the amount of thinking devoted to the expectation formation; The expectation q(T) is indexed by T because additional thinking will improve the expectation.

The investors estimate q(T) of R is assured to be a random variable sequence which must be analysed for convergence. The whole problem in Neurofinance is converted to a problem in estimation theory of random process. We convert the problem of finding the minimum variance unbiased estimate of population mean in the sample stochastics analysis.

To lever the randomness, the investor takes the mathematical expectation of Eq. (1) as objective function. That is, to minimizes

\[ E[(q(T) - P)^2] + MT \] \quad Eq. (2)

Now, rewrite of Eq. (2). Let R denote the “rational expectation” of P in the conventional sense of that term; R is the mathematical expectation of next-period's asset price P based on the true model of the economy and based on all information currently available. According to the definition of R, the forecast error (R - P) is uncorrelated with [q(T) - R]. it can be rewritten as

\[ E[(q(T) - P)^2] + E[(P - R)^2] + MT \]. Since the second term of this expression is outside the investor's control, the term can be neglected in the minimization; and the objective function may be shortened to

\[ E[(q(T) - R)^2] + MT \] \quad Eq. (3)
1. We give the derivation of convergence in expectation of Metacognitive power to the related expected market hypothesis.

2. The optimisation process suggested by the agreement of Metacognitive power to the usual expected return coincides with the calculations of minimum variance unbiased estimation process.

Assume that the investor reasons as if,
- \( r(T) \) is as accurate as a sample mean of \( T \) independent observations taken from a distribution with mean \( R \) and variance \( \sigma^2 \)
- \( f \) is as accurate as a sample mean of \( S \) independent observations taken from a distribution with mean \( R \) and variance \( \sigma^2 \)

The analogy suggested by (i), is that the investor's analysis is like a mental sample of \( T \) thoughts, each of which gives an error-perturbed bit of independent insight about \( R \), where \( \sigma^2 \) indicates the likely size of error.

Regarding (i), it might be assumed that the belief is indeed objectively accurate, implying that the costly estimator \( r(T) \) is objectively unbiased and consistent.

In that case, as \( 'T' \) gets large, \( r(T) \) would converge to \( R \). The investor would be rational since their thinking would converge to the right answer; but they would be boundedly rational since the convergence would take time.

The suggestion of (ii) is, then, that the investor's quick judgment is as good as \( S \) thoughts.

Assume that the investor takes (i) and (ii) to be true. The mathematical expectations are relative to the investor's subjective beliefs. The objective accuracy of the beliefs also needs to be considered.

Regarding (ii), it might be assumed that the investor's belief can be wrong, particularly about bias. The investor’s free expectation \( f \) is an initial guess, which may be based on a rule of thumb such as an adaptive expectation. It makes sense for the investor to treat the guess as unbiased in estimating \( R \) (otherwise they would use a different guess); but there is no good reason to suppose that an initial guess is objectively unbiased. Bias is one of the issues that are costly to figure out.

**Result 1**

\( q(T) - R + MT \) is an unbiased estimator of the population of the mean metacognition process.

For \( T \) large \( q(T) \) is the sample mean of the population mean \( R \). This using the law of large numbers \( q(T) \) approaches \( R \) as \( T \) tends to infinity

\[ E(q(T) - R) + MT \text{ tends } MT \text{ meaning } (q(T) - R) \text{ is the unbiased estimate of } MT. \]

**Result 2**

\( q(T) - R + MT \) is also a minimum variance of the population of metacognition process.

From

\[ \text{Var}(q(T) - R + MT) = \text{min} \{E[(q(T) - R) + MT]^2] \]  
\[ = \text{min} \{E(Q(T))^2 + E(R)^2 - 2Cov(q(T), R + MT) \} \]  
\[ = MT \]

This show that \( (q(T) - R) \) is minimum variance unbiased estimate.

Let us assume that another estimate \( q(T') - R \) where \( T' \) convex combination of investors’ thinking efforts of, \( \alpha X + (1- \alpha) Y \), as \( X \) & \( Y \) assumed as random variable.

This convex combination is also normal random variable. \( q(T') - R \) will be again minimum unbiased estimator.

From the above results, we give an alternative approach to the discussion of neurofinance over efficient market hypothesis. For the large observation costly metacognition process can be regarded as the efficient measure of market analysis for individual investor thinking process.

3. Conclusion and Recommendations

The interaction of controlled and automatic processes might be like a register policy or agency model in which a controller only steps in when an extreme state of the system (or unusual event) requires controlled processes to override automatic ones. The influence of effect on choices is a very general type of state-dependence (where the "state" is affective and is influenced by external cues and by internal deliberation and restraint). Instead of solving for equilibria in these interacting-mechanism models, solve for steady states or cyclic fluctuations.

Investors are a collection of complex structure which is prejudiced by diverse factors that affect their decision-making choices. Neurofinance is a new discipline in the era of finance. Here we use simple model which includes the metacognition thinking process, which can be identified through neuro technology by which an agent given to the investor the information which alternatively make a wise decision. Metacognition thinking will improve the expected accuracy of the final decision, and a choice that leads to the problem of infinite regress. This paper gives the alternative to Efficient Market Hypothesis when there is metacognition thinking process coincidences with the neuro and behavioural psychology while making the investment decision along with the other factors.
Instead of summarizing responses to changes by comparative statics, study impulse-response functions. Neuro finance needs design of new psychometric and technology for further investigation of individual investors behaviour.

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