NEUROFINANCE: TRADERS’ BEHAVIOR AND THE ROLE OF EMOTIONS IN FINANCIAL CHOICES

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INTRODUCTION

The core argument of the thesis will be the Neurofinance and the role of emotions in financial choices; how these emotions may influence positively or lead the traders on the wrong way, analyzing in details the latest studies of the neuroeconomic researchers and scholars. I will start retracing part of the history of the classic and modern economy, starting underlining how the psychological and social aspect of the individuals was at first part of the economic theories and only after suffered a clear detachment. Will be taken into consideration eminent sources such as Adam Smith, vanguard of the modern behavioral economics, and then described the evolution of the neo-classic economy towards a natural science. Phycology, left behind at the beginning, will then open up the road to a bunch of new studies, from Herbert Simon to the Nobel Prize of Kahneman and Tversky. Then will be described the two-system way in which our brain works and introduced the main cognitive bias. Anchoring and insufficient adjustment that guides investors to buy stocks decreased in value to exploit short term volatility while the decrease can be attributed only to a change in the company’s fundamentals; availability which interferes giving much more importance to stocks with a high mediatic coverage and the cyclic nature that permeate titles; representativeness that leads in the analysis of the short timeline, meanwhile investors should also focus on a wider one. These are going to be analyzed and corroborated with examples from the world of finance, discussing the main studies and researches from the brightest scholars in this field (Camerer, Templeton, Odean…).

Then the focus will move on the main topic of the thesis, I will talk about Neurofinance and the methods for recording the neural and physiological correlation of the human behavior and emotions. Will be explained in details the functional magnetic resonance imaging largely used in the neuroscientific field and fundamental to our study plus the encephalogram system. Not only analyzing the evidence of new experiences, but also for previous one. The study will concentrate on researches developed to demonstrate how past experiences may influence our current behavior. From Knuston we know that risk aversion activates different neural area from a risk seeking behavior and it can be triggered also from the regret deriving from previous experiences. Moreover, thanks to a field experiment done by Rocha, will be compared the behavior of “newbie” and "professional” traders. Text will focus on the regret experience, taking in considerations tons of neuroscientific tables and studies from Lowenstein, Rocha, Vieito and other scholars to determine the neural activation under financial decision making. Described in details the brain and cognitive implications of regret and risk aversion, focus will pass over the self-confidence and the role of the testosterone in financial decision. Describing the gender differences regarding
the production of the hormone and its role as far as it concerns the possibility of overcoming the risk aversion or, on the other hand, the risk of an excessive overconfidence. We will pay particular attention on field studies of Dario Maestripieri and Rustichini, that for long time studied the implication of testosterone on the behaviors inside and outside the field of the financial choices.

The last emotion that will be take into considerations is the envy and our innate goal to follow the best if our actions or solutions does not reflect our expectations. First of all, will be analyzed how the condition of social challenge can influence positively and negatively our judgment ability and our innate aversion to the risk. This analysis will be helped by an integration with a recent study conducted by Bault, on the different outcomes deriving from a social and a private financial performance. In the end the phenomena of the asset bubbles will be explained thanks to a field experiment by Alec Smith that discovered how the activation of certain parts of our brains are positively correlated to the creation of bubbles and the different classes of traders on the market that are the main protagonist of his instability. Then will be draw conclusions, making a summa of the whole studies integrated in the thesis and analyzing the possibilities that this discipline may give us in the immediate and further future.
I should have computed the historical covariance of the asset classes and drawn an efficient frontier…
I split my contributions 50/50 between bonds and equities.
Harry Markowitz, Economy Nobel prize winner 1990

1st Chapter: From Classic Economics to Behavioral Economics.

1.1 The Origin of Behavioral Economics

Has passed almost a century from when psychology and economic separated. In the beginning economy and psychology were closely linked the one to the other. Back in the 18th century “when economics first became identified as a distinct field of study, psychology did not exist as a discipline. Many economists moonlighted as the psychologists of their times”.1 Amongst the great economists that belongs to that period, such as Ricardo and Malthus, Adam Smith shines for his theoretical insights towards the human nature and behavior. Well known for his contribution to the creation of the modern concept of economy, sanctioning the end of mercantilism and the beginning of classic economy thanks to his masterpiece “The Wealth of Nations”, he wrote a less known book called “The Theory of Moral Sentiment”. This philosophical treatise contains incredible insight about human psychology and the nature of the individuals; a lot of which, now analyzed from a scientific point of view are currently under study. For example, Smith says: “As we have no immediate experience of what other men feel, we can form no idea of the manner in which they are affected, but by conceiving what we ourselves should feel in the like situation”2. This interpretation of the human behavior that Smith gives us will be analyzed furthermore demonstrating the emulating nature of men. Or: “We suffer more […]

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2 Smith. A. The theory of moral sentiment (1759) chap. 1: Of sympathy.
when we fall from a better to a worse situation, than we ever enjoy when we rise from a worse to a better.” That is a brilliant foregoing intuition of the loss aversion, discovered by Kahneman and Tversky that demonstrated that losses are twice as powerful, psychologically, as gains. Later on, with neo-classic revolution the vision of economy started to change. Denying the role of academic psychology and its impossibility to be ascribed in formal rules, somewhat paradoxical, economists tried to reshape their discipline. With a process called “Marginal Revolution” that started with scholars such as William Jevons and Carl Menger and the economist tried to transform their own discipline into a natural science. The process was slower than it may appear, in fact during the first years of 20th century writing of important scholars, such as Vilfred Pareto and Irving Fisher, were still soaked of psychological speculations. Moreover, John Maynard Keynes was still acting as if psychology was central into every economic argument, but during the half of the century psychological discussion started to vanish. No matter how hard fought scholars of very high standing such as Herbert Simon to keep psychology and bounds of rationality into account. Those kinds of research attracted attention of many but did not change the direction in which economy evolved. In the middle of discussion were the models of expected utility and discounted utility; both of them have a lot of testable and empiric implications and, in that times, was not possible to implement psychological traits into a rationality theory. There was not enough knowledge to understand how different emotions play a very important role in our decisions; also, there wasn’t instruments to measure the way in which our neural system works. That process brought neo-classic economist to build a model that could explain the allocation of resources based on 3 fundamental assumption:

a) People have rational preferences that can be identified and associated with values;

b) Individuals maximize their own utility and companies maximize profits;

c) People act independently basing on full and relevant information.

The subject that comply with every one of those points has been called Homo economicus.

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3 Smith, A. The theory of moral sentiment (1759) chap. 6.
6 Menger, C. (1871) “Principles of economic”.
7 Initiated by Daniel Bernoulli in 1738.
1.1.1 Homo Economicus and Irrationality

He is a perfectly rational being who acts to obtain the highest possible satisfaction for himself given all the available information and constraints, natural and institutional, on his possibilities to attain goals. A term coined by critics of John Stuart Mill\(^8\) and then used and often abused by a wave of economists, that built mathematical models on these assumptions. The whole branch of microeconomic is written by the hypothesis that the subject analyzed is perfectly rational.

Let’s make an example.

![Indifference curve diagram](image)

In this graphic, the curve that merge every single point (or market basket) is an *indifference curve* and relying on the theory of expected utility for a subject every single point is worth the same. On the point A the individual receives 14 oranges and 1 mango and it is worth the same as the point E where he receives 5 mangos and 1 orange. This kind of proportion is always working and the subject will never change his mind about those preferences.

Clearly this kind of representation is a simplification of the human needs and it is just a model that helps us to understand how does the reality works, but those models are far away from the truth. We are not perfectly rational. We are not machines and we commit errors all day long even in the simplest things. In America, almost 60% of the adults can be considered overweight or obese. Almost 1.9 billion of adults is overweight and according to WHO data’s\(^9\), in North America, UK, East Europe, Australia and China obesity rates have doubled since 1980. Also, looking at WHO data’s is possible to notice that 500,000 people die

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\(^9\) Data available at the site [http://www.who.int/topics/obesity/en/](http://www.who.int/topics/obesity/en/).
of tobacco and alcohol abuse. This doesn’t mean that every alcoholic and every obese is irrational, but that mean that they probably don’t make the best choices in their life. Not by chance that kind of people are willing to pay someone to help them. To be perfectly rational means to make undistorted predictions. In other words, we can make mistakes trying to predicts some phenomena, but those predictions cannot be systematically and predictably wrong.

The difference between a human and a *homo economicus* is that humans do mistakes in a predictable way.

1.2 *Back to Psychology*

Later scientists began to shed more light on the brain as an information processing device. Here Amos Tversky and Daniel Kahneman tried to compare their models of decision making under risk and uncertainty to economic models of rational behavior; they demonstrated consistent fallacies into the expected utility theory\(^\text{10}\) and discounted utility\(^\text{11}\). New studies about the information-processing process of our brain allowed to study new topics such as memory, problem solving and decision making. Here Kahneman and Tversky distinguished themselves thanks to a whole new study published on 1974 on Science, talking about heuristics, mental short-cuts that creates wrong probability judgment that deviates from statics principles. In 1979 their publication about *“Prospect Theory”* had an incredible influence amongst the whole economic field. Nowadays has been created a method that almost every behavioral economic research has followed:

1) Look at normative assumption and models such as expected utility theory used largely by economists;
2) Find out anomalies and demonstrate violation of the assumption/model;
3) Use these anomalies to create alternative theories that can explain subjects’ behavior.

A fourth step should the test of our new rules into the field, as Richard Thaler and Cass Sunstein tried to do, applying their studies to a bunch of fields\(^\text{12}\). In this paper, we are going to discover a brand-new category of research called *“Neurofinance”*, that examine the nature of cognitive processes engaged in

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\(^{10}\) Kahneman & Tversky 1979, Richard Thaler 1981.
\(^{11}\) Lowenstein & Prelec 1992.
acquiring and processing information in financial decision making. But before we must the explain heuristic and the common bias that our brain does in our decision-making process.

2nd Chapter: How Does Behavioral Economics Work

2.1 Behavioral economics methods

The main goal of behavioral economics is to find empirical evidence of the psychological traits and mind bias that distinguish humans from the individuals described in the models largely used in the economics themes. To integrate psychological implication inside an economic model, scholars relied on the same study method of the other economists: the experiments. Thanks to our advance in technological field is now possible to accumulate data on the field and the evidences are also generated by computer evidence\textsuperscript{13} and brain scans\textsuperscript{14} that will largely be explained later.

2.2 Two systems

In order to understand why we act in non-rational way, it must be taken into account the way our brain works. As we said before 70’s was not possible to give an answer to this question. Thanks to Kahneman\textsuperscript{15} and Tversky research now we understand what lies beyond the scheme of our decisions. Our fast and intuitive judgments are hidden between the automatic instinctive actions and the reasoned operations. This kind of distinction between slow and fast reasoning has emerged to give an answer to the bias in choices under uncertainty. Our mind is divided in 2 different systems. System 1 is linked to: unconscious reasoning, implicit, automatic, and low effort operations; System 2 to: conscious reasoning, explicit, controlled and high effort operations.

\textsuperscript{13} Angeletos et al., 2001.
\textsuperscript{14} McCabe et al., 2001.
\textsuperscript{15} Daniel Kahneman (25 October 2011). Thinking, Fast and Slow.
System 1, that may seem like the result of an entail of our primitive nature, is a fast process of recall from the long-term memory that requires no efforts. It does rely on our personal experience and as much more familiar a certain operation is for us, the more is the probability of activating system 1. Chess players are the best empirical example. Results from a research conducted by William G. Chase and Herbert A. Simon on the perceptual structures the chess players perceives shows those results: a newbie of chess needs a lot of effort to calculate what should be the next move, this operation may take a lot of time and mind efforts. On the other hand, a chess master can rely on his long-time practice, he can call back from the memory automatically what, in his experience, should be the next right move cutting the three of alternatives immediately.

Masters search through about the same number of possibilities as weaker players -perhaps even fewer, almost certainly not more- but they are very good at coming up with the “right” moves for further consideration, whereas weaker players spend considerable time analyzing the consequences of bad moves.16

This mean that a large part of our mind reasoning interacts with automatic process that comes from a direct link to our long-term memory; all of this is not under our control. The consequence is easy to deduct, if the elements that our mind calls back from memory aren’t under our control and don’t follow statistic and mathematic rules, because they are just a result of our experience and are the result of an evolutionary need that doesn’t follow logic, our judgment is inevitably

16 William chase and Herbert Simon perception in chess cognitive psychology 55-81.
lead to a bias. This limit to our computing ability is the base hypothesis to the theorem of "Bounded Rationality"\textsuperscript{17} formulated by Herbert Simon. In Simon’s theory, our computing abilities are limited and our limitation inevitably lead us to bias. During our life, we come across tons of information; as said before the more the information we get for any given task, the more is the probability to trigger one mental short-cut that helps us avoid a lot of calculations and this mental shortcut is also the result of our limited computing abilities. Those mind processes that helps us overcome the wall of our mind limits are called \textit{heuristics}.

\section*{2.3 Heuristics}

This idea of heuristics made Kahneman and Tversky start a research program called “\textit{Heuristics and Bias}”\textsuperscript{18} to discover the most common heuristics used by humans in their judgment ad decision making. The main goal was to categorize those heuristics that, as said in the previous paragraph, instead of help us discover an approximate solution to our problem, lead us systematically and inevitably to mistakes. Here we are going to explain some of the most common heuristics used by us in our everyday life.

\subsection*{2.3.1 Anchoring and Insufficient Adjustment}

‘In many situations, people make estimates by starting from an initial value that is adjusted to yield the final answer. The initial value, or starting point, may be suggested by the formulation of the problem, or it may be the result of a partial computation. In either case, adjustments are typically insufficient\textsuperscript{19}. That is, different starting points yield different estimates, which are biased toward the initial values. We call this phenomenon anchoring.”\textsuperscript{20}

Experiments show us that we use anchoring in almost every task of our life. For example: drivers coming out from a highway usually drives faster than the average when entering a city because they are anchored to the speed of the highway.

In finance, we can easily be victims of the anchoring effects. Investors usually invest in stock of companies that fall considerably in price in a very short amount of time. The base idea is to exploit the short-term volatility to get a revenue but, sometimes, stocks decline in value due to changes in their fundamentals. Let’s suppose that stock ABC in the last years had very strong revenues and its share price increased from 200\$ to 800\$. Meanwhile on the

\begin{thebibliography}{9}
  \bibitem{17} Herbert A. Simon. (1957) Models of Man: Social and Rational.
  \bibitem{19} Slovic & Lichtenstein, 1971.
  \bibitem{20} Tversky and Kahneman, 1974.
\end{thebibliography}
company’s big customers, who gave a contribution for 50% of ABC revenue decided to not renew its purchasing agreement. Price of ABC share drops from 800$ to 400$. By anchoring to the previous 800$ investors may erroneously believe that ABC is undervalued. In fact, shares are not on discount, instead the drop-in value is attributed to ABC fundamentals change. Investor has fallen prey to the anchoring effect.

An excellent research has been conducted by Gregory Northcraft and Margaret Neale21. They asked two groups of professional real estate agents to evaluate a property. This property had a value of 250.000$ that after 15 years became worth 900.000$, an astonishing price. After some time, they were not able to sell the house because the local company failed and nobody was able to afford the house for 900.000$ and the only way to sell it was to reduce the price for 10%. Almost nobody reduced the price, because they were anchored to the previous price, even if with a 10% discount, the revenue was more than three times the initial price.

### 2.3.2 Availability

A different heuristic is the availability. This heuristic help us to make a difficult judgment and rely on our ability to have immediate examples of a specific topic in our mind. The heuristic is positively related to the magnitude of the event happened, the proximity in time and the repetitions. In fact, as much the event is big, recent and repeated in time, the more is easy to judge the event as an event of high probability. We can easily find distortions of availability into the market, for example: instead of valuing the possibility of an equity to increase in value, we use our availability heuristic to judge that possibility. The result is that equities with a big media coverage will be considered more likely to increase in value, instead of equities which nobody ever listened to. Moreover, in a research conducted by Byunghwan Lee, John O'Brien and K. Sivaramakrishnan22 they tried to expose the properties of business cycles to predict availability bias in analyst’s growth forecast. They showed the availability heuristic to play a role in analysis of forecasts and influence investment. Another example is illustrated by Franklin Templeton23; he asked individuals in 2008 after financial crisis how they believed the S&P 500 Index (an Index made by Standard & Poor’s that follow the 500 best companies in USA) performed in the next years 2009, 2010, 2011.

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Availability heuristic was triggered immediately and 66% for 2009, 48% for 2010, 53% for 2011 stated that the marked was going to be flat or down. The S&P 500 Index saw returns for 26.5% in 2009, 15.1% in 2010 and 2.1% in 2011. Lastly a research by Sefa Hayibor and David M. Wasieleski showed that also the ethical behavior in organizations is affected by availability, in fact the availability of others who believe that an act is morally acceptable is positively related to other’s perceptions of the morality of that act.

### 2.3.3 Representativeness

Another heuristic that is largely used to judge the probability of an event under uncertainty is the representativeness heuristic. Instead of judging the probability of a given event we judge the likelihood of the event to a prototype, or how much this event is representative of a class. In fact, to judge the similarity of an event to a class it’s easier than judging its probability. Investors usually correlate the attributes of a company (for instance, managers, product and marketing) to the quality of the investment. For example, investors, might be tempted to forecast the future earning of a company by taking in consideration only the short histories of high earning growth observed in the past. This forecast may cause an overpricing in the companies’ stocks but, high earnings growth, can be due to chance. In fact, is unlikely that high earnings in a short-term period repeat themselves and this may lead to disappointment. If future earnings then are lower than the forecast, stock price could drop considerably. To be more specific, the representativeness heuristic tends to distort the regression to the mean process, that explains why sometimes a bad portfolio may perform better.

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25 (DeBondt, 1993).
than a good one. To be more precise let’s look at this image:

![Graph showing a normally distributed series with a magnified section showing fluctuations.](image1)

A forecaster looking at the magnified may assume that this is a continuously increasing series, but this is part of bigger series, that may deviate from the forecaster prediction.

So, for a good investor, is crucial to keep in mind that a small series is not representative of a bigger one and, looking at the regression to the mean, his forecast may be completely wrong. Investigating the trend of an important stock, Dhar & Kumar\(^\text{27}\) found out that in a five years’ period investors (more than 62,000) preferred to buy the stock in period that showed abnormal returns instead of exploiting a discounted price period.

### 2.4 Prospect Theory

The revolutionary theory that changed the way in which economists looks at decision making under risk is the “Prospect Theory”. This theory was created and developed by Daniel Kahneman and Amos Tversky in 1979 and was so astonishing that granted to them a Nobel Prize in economics. This theory says that


\(^{27}\) Dhar & Kumar (2001).
when evaluating alternatives that involves risks, people make decisions based on the potential value of losses and gains rather than the outcome and when evaluating losses and gains people use the heuristic. Because of the relevance that this theory assumes for behavioral economic we must go deeper in details. Given a task people first analyze it using heuristic, of course when evaluating their preferences (differently form the expected utility theory) are affected by variations of outcomes and options, violating the invariance assumption. This is the base of the framing effect\(^2^8\), in fact people react differently depending in which way a task in presented (as in the Asian disease problem)\(^2^9\). Moreover, they set a reference point. This is crucial because Bernoulli’s model was reference-independent but here the value assigned to a given wealth vary depending on the initial state of wealth of the decision maker. A big role is played by the loss aversion. First, people become risk seeking in a situation of loss, and risk averse in a situation of gain. Then, when settled a reference point, losing wealth under this point is considered by individuals twice as bad as gaining the same amount of money. For example, losing 50$ is equal to a gain of 100$, as we discussed at the beginning, referring to the Adam Smith’s quote. The value function is asymmetrical and is deeper for losses than gains, indicating that losses overweight outcomes.

![value function graph](https://en.wikipedia.org/wiki/File:Valuefun.jpg)

To conclude this short introduction to the prospect theory, we must say that in this model people have a distorted vision of probability, in fact they “overweight small probabilities and underweight large ones; do not choose stochastically dominated options when such dominance is obvious; ignore very

\(^{28}\) Tversky & Kahneman 1986.

\(^{29}\) Tversky and Kahneman 1981.

small probabilities and code extremely large probabilities as one”\textsuperscript{31}. Moreover, people have a diminishing sensitivity to gain and losses, in fact the more the size of gain and losses relative to the reference point, the less the marginal effect of a gain or a loss will be. Lastly, this is the formula that Kahneman and Tversky wrote for the evaluation phase; where: $V$ is the expected utility, $x_i$ the potential outcomes, $p_i$ their respective probability and $v$ is a function that assigns a value to an outcome.

$$V = \sum_{i=1}^{n} \pi(p_i)v(x_i)$$

Now that the historical evolution of behavioral economics is explained as the main heuristic and biases and prospect theory, it’s time to go deeper. In the next chapters, we are going to analyze the implication of the mind biases in investor choices and, above all, their correlation with our neural system.

\textbf{3rd Chapter: Neurofinance}

\textbf{3.1 Brain Imaging}

Thanks to the new technologies is now possible for us to study our financial choices in a deeper way. Before we were studying human biases just by looking at the result of our tests; we had a best choice and usually people choose the wrong one just because they were driven by different emotions and mind biases. Now we are going to look at the physiological and neural implication of these choices studying how different parts of our brain activates just because we have an innate personal disposition to the risk. But we are not just simply going to study neural implication of human biases, we are going to see how different emotions can activate different parts of our neural system and how this activation can influence our financial decision. One of the most important implication is that our emotions aren’t triggered just by our actual situation, but previous experience of failure or good result can activate emotions that play a very important role in our process of choice. Brain imaging is the most used neuroscientific method that involves a detailed comparison between people performing different tasks\textsuperscript{32}. The


\textsuperscript{32} An experimental and a control task.
divergence of images taken while performing those tasks provides a highlight of the brain areas activated.

3.1.1 Functional magnetic resonance imaging

We have different methods to study how in which manner our brain works in a decision. The newest technique is the functional magnetic resonance imaging (fMRI). Experiments involving the use of MRI need to be done in places like hospitals, because it uses strong magnetic fields, necessary to move diploes from a place to another and then study how those diploes moved.

It is a very useful instrument because it gives us very good and precise information about which neurons activated in which place of the cortical and subcortical areas. The problem is that MRI’s process last for a very low temporal window and for statistics data is usually necessary a data sampling of at least 2 seconds to give use reliable information about the activations of our neural system. Studies shown that our decisions involving financial choices usually activates the orbitofrontal cortex, the medial prefrontal cortex (MPFC), the
amygdala, insula, the nucleus accumbens (NAC), Striatum (Str) and other neural structures as shown in the picture.

Another important study conducted by Kuhnen and Knutson show us that a risky choice and risk-seeking attitudes are preceded by the activation of nucleus accumbens, while insula activation usually preceded choices without risk or risk-averse attitudes.

A different study about loss aversion and risk has been conducted by De Martino, Camerer and Adolphs that show us how two rare individuals with focal bilateral amygdala lesions, even if able to distinguish a variation in the experiment in terms of expected value and risk, showed a dramatical reduction of the loss aversion suggesting that our innate risk-averse stimulus is closely connected to the amygdala.

3.1.2 Electroencephalogram

Another possibility to study our neural system under circumstances that involves financial choice is given by the Electroencephalogram (EEG). When our neurons activate in different cortical areas they produce an electric current that is weighted and measured by a set of electrodes. Then using a technique capable of mapping the electric field produced by our neurons called “LORETA” (Low Resolution Brain Electromagnetic Tomography) we can easily locate which sets of neurons activated during a brain process using the EEG activity.

36 De Martino et al. (2010).
3.2 Previous experiences affect future decisions: Regret

A very important research in this field has been conducted by Rocha, Vieito and Rocha\textsuperscript{37}; the same experiment has been conducted again by Lima Filho, Rocha and Massad\textsuperscript{38}.

In the first experiment, we have Portuguese undergraduate students from financial course. In the second one we have professional traders from various companies. Both had a portfolio composed by 200 stocks of 7 different companies. They had the opportunity to made 100 different investment decision with the possibility to hold sell or buy stocks. During all the process, they used EEG to study which area of the brain was involved in each process. “These sources are widespread over the entire cortex and are mostly located bilaterally at Medial, Middle, Superior and Inferior Frontal Cortices, as well as at Rectal and Orbital Gyrus (areas with $x$ coordinates greater than 20); Paracentral, Precentral, Postcentral Gyri and Inferior Parietal Lobe ($-25<X<Y<X<-30 \text{ or } Y>30$); and Precuneus, Cuneus, Fusiform and Lingual Gyri, Superior, Middle and Inferior Occipital Cortices ($X<-65$). However, source location differed for both experimental groups.”\textsuperscript{39}

\textsuperscript{37} Rocha, Vieito and Rocha (2013).
\textsuperscript{38} Lima Filho, Rocha and Massad (2013).
\textsuperscript{39} Text and the image below, both coming from the paper “Neurofinance: How do we make financial decision”. Created by Armando F. Rocha, Joao Paulo Vieito and Fabio T. Rocha and published by Armando F. Rocha in (05 September 2017).
It's easy to understand from the image that each different group had very different area of activation, but is very important to notice that the overall result was quite the same for both groups. One possibility is that each group had different ideas regarding the market because the market in San Paulo and the Portuguese Market were different. This proposition was supported by the fact that the 2 groups had different initial PCA pacts. But that was not enough to explain the result of the experiment, in fact a deeper analysis showed that those differences in patters are due to the initial knowledge and experience of the traders. Beginner traders have a different neural path from the expert traders.

This information assumes a very important role into our discussion. In fact, a previous experience or a previous emotion can change the way in which we act. The loss aversion can be a result of previously failed financial operations, our sense of fear to lose again money can make us choose the riskless operation instead of the risky one. Going deeper we can refer to “expected” and “immediate” emotions. Expected emotions are those that we usually associate to a possible outcome of our decision. As stated before if I have the possibility to buy a stock, but my mind “remembers” me the possibility of a failure, I will probably choose not to buy that stock and vice-versa. Instead the immediate emotion are the emotions that we can feel only in the moment in which we take a decision. As a further analysis, in my opinion, immediate emotions may become in the future the new expected emotions. In fact, experiencing a financial failure today, tomorrow will make me think twice when going to buy stock on the market. So, connecting

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to the expected utility theory, we only have a partial knowledge of our preferences and looking at it in a different way shows us how emotions are not an unpredictable result of our choice but a part of the decision-making process.

From now on, we are going further in the analysis of the emotions and looking at how they can influence our financial choices. Going back to irrationality we may argue that emotions, such as regret, can make us act irrational. We have a big opportunity of investment but our fear of losing money stops us from making that investment. Well, emotions are between the rationality and the irrationality, or maybe even outside that kind of argument. Emotions are just a way in which we adapt ourselves to the world. The “emotional response” represent the mobilization of the organism act to face the environment, to give us the opportunity to adapt in a “Darwinian way”. So, when our mind try to avoid bad feelings, acting for example the loss-aversion, it is an absolutely rational way to avoid a possible problem. The regret is a feeling that helps us learn from our mistakes: we can compare our decision with many possibilities (it might have been like this if I…). Learning from previous experiences is probably the only way thanks to we survived through the ages. Now, to understand how regret work in our financial choices I am going to follow a study conducted by Gabriele Chierchia and Giorgio Coricelli that studied a group of patients affected by heavy injuries to the orbito frontal cortex. As shown in picture:

This kind of person have full cognitive process, but they clearly have problems especially during financial experiments. They tend to create serious disasters in the stock market and they also show problems in the everyday life,

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with their families and chronically falling into gambling. On the other side, there was patients without any brain injury. To study how regret may act in our mind process, in this experiment they gave to those patients the possibility to choose between two options. The first time they only receive the result of their choice, whereas the second time they receive the result of their choice plus the result of the discharged option.

This to show that the first-time patients may feel disappointment for a bad result of their investment, on the other side the second time, knowing the result of the other option they may also had felt regret. The result of this experiment was that patients with orbito frontal cortex injured can feel disappointment, but they cannot anticipate the feeling of disappointment! They cannot feel regret. On the other hand, we have patients without brain injuries. The first time they have done the experiment, they felt bad when making the worst choice. The second time they felt even worse, knowing that the other options were clearly better than the one they choose.

If, as said before, our regret is an adaptive function that our mind evolved to survive, the lack of this emotion can partially explain why patients with orbitofrontal cortex damage tend to make financial disasters.

Analyzing the neural function of the subjects Coricelli and colleagues discovered that the accumulated experience and then the feeling of regret are both associated with the activity of the amygdala and the orbitofrontal cortex. So, those parts of our brain are fundamental in the process of adaptive learning; to change our behavior due to different circumstances. As said before our brain learn trough experience and the feeling of regret helps us and force us not to repeat that experience again. Is a double-edged weapon, in fact it surely helps us avoiding bad situations but, from the other sides, looking specifically into the market operations, it leads us to avoid risky but maybe rewarding operations. As shown in the figure below we notice how the experience tends to accumulate during our life and the sense of regret is anticipated more and more easily as much as we collect experience of a certain topic, while collecting experience from this actions activate the brain areas dedicated to the learning process.
Looking at the result of this study a lot of behavior on the market can now be seen under a new perspective. For example, when we choose how to invest money for our retirement we usually take 50% bond and 50% equities. It seems prudent from an external point of view to not risk all our money in equities even if the expected utility is very high. By not investing 100% of our saving into equities we are unconsciously avoiding regret. We know that the expected utility is very high, but our mind tells us to avoid this investment because there is a high probability that we will lose all our savings and feel a strong regret toward our past actions.

A more accurate analysis, shows us that is even possible to distinguish in financial market a past regret and a future regret. To the participants of an experiment were given a title that can be held for a maximum of 50 periods and every 15 periods they can choose to hold or to sell this title. Analysis on the brain activity of the participants to test had a great result. They felt a past regret towards the maximum peak of the title value, when they choose to hold the tile instead of selling it. In case of selling the title, on the other hand, they felt a sense of regret toward the expected maximum value that the title may have reached. On the real market this effect can be seen easily: the past regret will lead us to hold the title until he reaches a value close or higher to the past highest peak. Instead the possibility to follow the trend of the title in the future will also prevent us to exit

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43 (Fioretti, Vostroknutov, e Coricelli, 2017).
from the market. This is a clear effect of the status quo bias and the disposition effect.\textsuperscript{44}

3.3 Self-confidence: testosterone and gender differences

Another important aspect of our mind is the total and blind self-confidence in our decision. Is scientifically proven that every single student considers his capabilities over the average and almost every investor think about himself as someone who is surely able to get a yield over above the average. In 2006 James Montier\textsuperscript{45} found out that 74\% of professional fund managers believed to achieve an above-average performance and the other 26\% viewed themselves as simply average. Unfortunately, only 50\% can be above the average. A lot of studies in this field of neuroscience has been conducted by Terence Odean. He demonstrated that driven by an overconfidence in their work investors tend to trade way too much. And trading by having a wrong belief in our capabilities lead us to a consistent loss of money\textsuperscript{46}.

Deeper analysis show that investor learn from good and bad news in an asymmetrical way, showing that they are affected by deviations from a Bayesian learning. Noise traders\textsuperscript{47} move a massive amount of money from the private funds to the financial institutes, for example in Taiwan it represent the 2.2\% of internal domestic product\textsuperscript{48}. Psychologically the pride we manifest towards our successful actions is the opposite of the regret. Whenever we obtain something in our mind it is represented as the result of our efforts and skills. Like the regret keeps us away from repeating actions that ended up in a failure in the past, pride will unconsciously prompt us to repeat those operations that showed to be successful, even if they don’t have a clear material return or even if they are unpleasant to do. This is related to a sort of hidden challenge that every one of us have with other subjects. We are unconsciously pushed to do better than the others in almost every sort of challenge as showed by Camelia Kuhnen and Agnieieszka Tymula:

“In our experimental setting, people work harder and expect to rank better when told that they may learn their ranking, relative to cases when feedback will

\textsuperscript{44} The disposition effect is one of the most common bias in the financial market. Investors have the tendency to sell shares whose price is increased in value, while keeping assets that has dropped in value. This is not a rational behavior because, usually, stocks that had a good trend in the past months will have a good trend in the following months and vice-versa.

\textsuperscript{45} Behaving Badly, James Montier, 2006.

\textsuperscript{46} Do investors trade too much? Odean T. (1999).

\textsuperscript{47} A subjects whose decision to buy, sell or hold are completely irrational and erroneous.

\textsuperscript{48} Barber, Lee, Liu and Odean (2009).
not be provided [...] feedback helps create a ratcheting effect in productivity, mainly because of the fight for dominance at the top of the rank hierarchy”⁴⁹.

This relation between a challenge and the constant seeking of excel and shine over the others is a male prerogative. As showed Bertrand and Hallock only 2.5% of the highest paid executives in America are women⁵⁰. This result is often referred to a gender discrimination in the workplace but, Gneezy, Niederle and Rustichini try to attribute this gap to lack of competitiveness of women in the high-ranking fight⁵¹. The higher will of competition of men is closely related to the presence of testosterone, a male sex hormone that plays a key role when it comes to obtaining and maintaining a dominant position.⁵²

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Higher testosterone levels can lead to differences in thought and behavior, in details referring to a modification of the brain structure passing from prenatal life to the end of the puberty. When it comes to prideful and self-confident behavior testosterone is always present and any researches showed how high level of testosterone helps to overcome fear and situations in which our mind is exposed to a strong stress; it is also proven that after a competition winners always show a big presence of testosterone and, thanks to the hormone, tend to act more aggressively. Situations of challenge drive out body to produce more and when produced it lets us act as if in a situation of challenge.

As said it reduces the level of fear; coming back to financial choice it may lead men to act in a daring way and, in some cases, to completely remove our loss-aversion. One of the most representative study of the differences between men and women in financial choice and the influence of testosterone related to a more prideful and reckless choice has been conducted in the University of Chicago by Paola Sapeinza, Luigi Zingales and Dario Maestripieri. This study start assuming that women are generally more risk averse than men and the scientists investigated how variations of risk aversion in financial choice can be related to a variation of testosterone in the salivary concentration of the subjects. Results shows that, first of all, men have a significant lower risk aversion than women, and this gap can grow larger as much as the concentration of testosterone in the saliva increases. As shown in this picture men have a clear natural predisposition to a higher level of testosterone.

Second, there was a negative correlation between the concentration of hormone in the saliva and the risk aversion across men and women, however, when the analysis was separated between genders, the effect of testosterone on the risk aversion for men wasn’t even statistically significant, meanwhile for women the relation was incredible. Almost 7 times greater.

Lastly, a study conducted by Rustichini A. and colleagues\textsuperscript{56} shows that the presence of the testosterone and the cortisol may lead to risky financial choices and market instability. Specifically, they found out that an increase in the hormone level of cortisol and testosterone predicts a subsequent shift of the investment

towards riskier assets. Testosterone acts by increasing the optimism in risky operations while cortisol affects risk preferences directly.

3.4 Following the best, envy and the creation of asset bubbles

As far as we have seen our brain, thanks to the experience, tends to avoid dangerous and risky situations, but at the same time our nature leads us to shine over the others. These two propositions are in contradiction, because to excel and to be recognized as better as other people sometimes it takes risks. Last behavior and emotion we are going to analyze is the perfect bond between the two: the ability of people to emulate. In 2010 Bruguier and colleagues\(^{58}\) studied the so-called “trader intuition”, the ability of outsiders’ traders to quickly catch the signals about future dividends from the insiders even though the trading process is completely anonymous. If we don’t have the possibility to sit down on the top, we can retrace the behavior of who does it. This comes from the same idea of the regret. We learn from our past action that the choice we made wasn’t the best, for this reason we feel guilty, but we feel twice as bad because the person that took the right choice now is in a better situation than us. This emotion of envy goes straight into the social aspect of our society. We understand, using as point of reference our social status, that we can increase our position in the society just by behaving as the best does, but our will of excel sometimes is used as a bait. For

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\(^{57}\) Same study as above, from Cueva and colleagues. It shows the difference of investment in low and high variance stocks. In both experiment after the administration of cortisol and testosterone the investment in high variance stock had an enormous increase.

example, for most girls the peak in our society has been reached by Hollywood actresses. They want to be as beautiful and popular as they are. Companies knows that, and using those actresses as guests of their publicity send this message “You want to be as beautiful as she is? Use my beauty product, is the same one that she uses”.

At the same time, we don’t always buy product that may have the best utility for us, sometimes we buy products that communicate our social status to the others. A big and expensive car may be useless in a city, it’s hard to find a park and sometimes inside have less space than a family car, but it communicates that we have a high social status.

In finance now is very important to understand if for a subject a personal winning can create a more pleasing situation of a winning over another subject. In fact, the study that I am going to show examines the social comparison of a risky choice. This experiment tries to explain the differences between a positive outcome and negative outcome respectively in a private situation and in a social situation.

The general result was the that the brain structure related to the incomes and rewarding situation, the striatum, showed a higher activity when our gain was more consistent if compared with the prize of the other participants; showed less activity in a private winning case and even less activity when comes to social losses and private losses. Social gains showed also a high activity of the medial prefrontal cortex and they induced participants to more risky choices and competitive behaviors in later experiments.

59 The so called “Verblen effect”, an irrational consumer behavior where high-priced goods sells more than their low-priced substitutes. May be triggered by the assumption that higher price means higher quality or the desire for prestige items.

60 Bault N, Joffily M, Rustichini A, Coricelli G. Medial prefrontal cortex and striatum mediate the influence of social comparison on the decision process.
As shown in the picture above, adapted from the research of Bault, we can clearly see how strong is the activation of the prefrontal cortex after a winning that involves a social performance. Instead private and social losing aspects are all in the average and under the average of the signal intensity.

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61 Figure n.3 from the same study as above.
Here in this image, on the other hand, is possible to see the striatum activity, that shown almost the same result and activity as the prefrontal cortex, that is a higher activation subsequent a successful result in a social situation.

Knowing that the social aspect is dominant in our choice, is it possible to assume two aspect of the risky choice. First, if we have a preference over the social aspect, as most people do, our behavior will be highly influenced by the actions of the winner. Our innate envy will lead us to follow and copy the actions of the best. Second, if we have a preference toward the pure win, no matter if it is related to the social or private aspect we are going to assume a behavior of dominance, clearly opposite to the one of the mass. So, the envy is the first cause of the so called herding effect\textsuperscript{63}. This may also involve a lack of confidence towards our actions. The herding effect can be very harmful for the market, because it’s the main cause of the market mass euphoria towards a very risky and uncertain choice (Bitcoins, for example) and the subsequent creation of an economic bubble.

\textsuperscript{62} Figure n.4 from the same study as above.
\textsuperscript{63} Mental bias and instinct characterized by a lack of individual decision-making, causing people to act as those around them does. In finance herding effect cause individual to invest only to follow the investors who gravitate around one stock. Linked to the fear of regret.
About economic bubbles Alec Smith and colleagues\textsuperscript{64} conducted a research to investigate their formation. In each of 16 sessions the neural activity of an average of 20 traders were analyzed by functional magnetic resonance imaging. It works by giving to the subjects 100 units of experimental currency (risk-free assets, or liquidity) and 6 units of risky assets (stocks). Each period the risky one paid a dividend of “x” and at the ends of 50 periods the assets would have been exchanged for 14 units of liquidity. Having this parameter unambiguously determined a fundamental value of the risky assets, but its price was always above 14, indicating a persistent bubble. The median price peak was of 64.30 and it always lead to a crash, resulting in a price similar to the fundamental value of 14.

In conclusion is easy for the researchers to find three different categories of individuals inside the experimental market:

- Subjects that sell their stocks at the beginning of the game at the fundamental value, waiting the end of the experiment to get the final cash;
- Subjects constantly buying stocks at the beginning of the bubble and even after that the bubble reached its peak;
- Subjects that buy stocks during the growth period and that sell the stocks just before it reaches its peak.

From different behaviors, we may notice different activations in the cerebral area. The activation of the nucleus accumbens is related to the growing trend of the market and this activation reaches its peak in the exact moment in which the price is at the maximum level. As we considered before the activation of this neural area is related with a risk seeking attitude and the possibility for the individual to exploit the market. The one buying following the growth of their nucleus accumbens’ activity are those victims of the exuberance and also the one

\textsuperscript{64} Smith et al (2014).
\textsuperscript{65} Smith et al (2014) figure 2.
who get less money. Smart traders on the other hand, follow the signals received from the insula cortex, the area related to the risk aversion and the uncertainty in financial choices. They know that the growing trend cannot continue forever and before that the price drops they sell the stock. Do not receiving any statistic signal, must understand it from a sort of intuition.

CONCLUSIONS AND CONSIDERATIONS

We have analyzed how, starting from the assumption of the economic theory that we are completely rational, our mind and actions are always deviated from a mathematical rationality to a human irrationality. Human irrationality intended as the way in which our brain leads us to the option that we consider the best for our surviving, but that clashes with the economic theory.

Now, thanks to the most advanced technology we are able to interpret and analyze our behavior and try to address our action in a more rational way. In details, we have analyzed three different emotions, that are the main cause of financial instability on the market. First of all, we have the regret. Studying the prefrontal cortex, the orbito frontal cortex and the amygdala using a functional magnetic resonance imaging in the same moment as we compute our financial choices, we know that our action may be subject to a previous experiences’ regret or a future one. As noticed before regret is one of the most useful tool in our

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inventory. It helps us avoiding financial disasters and a lot of everyday problems, things that happens frequently in patients affected with orbito frontal cortex damage. At the same time, it makes us avoid risky choices. Being able to monitor our prefrontal activation during financial decision may help us understand if seeking a risk is either a bad or a good idea and in the extreme case it could lead to a sort of prevision of when the peak of an asset is reaching its maximum. The next goal of Neurofinance will be changing the double-edged sword aspect of the regret. Mitigating this emotion and making it available only as a tool of prevision of a bad trend of an asset.

A completely different treatment must be reserved for the overconfidence. A blind self-confidence and a high level of perceived competition demonstrated, in the experiment of Rustichini, a consequent instability of the market. Moreover, we understood how men and women have different levels of testosterone and consequently a different approach to the social competition. The higher level of this hormone, that is possible to notice in men, can be addressed to a natural attitude towards competition and a primordial instinct to excel, for obtaining the highest social position. This can be translated in riskier behavior in financial choices. So, from an objective point of view, women thank to their nature, have a lower possibility to create instability on the market and a better predisposition to the role of trader. By the way, this is not a constant rule. In fact, as show in the image at page 27, in a non-competitional environment, the concentration of the testosterone in women can be much more concentrated than in men, increasing the self-confidence and the risk seeking behaviors by 7 times. The risky and dominant behaviors connect immediately to the envy and the creation of the bubble assets shown in the experiment of Alec Smith.

The envy is the natural consequence of our will of prevail and excel, but this innate exuberance can lead to disaster in markets. The concept of envy and the subsequent behaviors can physically be explained by the combination of a high level of testosterone and the activation of certain parts of the brain, precisely the nucleus accumbens. By knowing this base concepts Neurofinance scholars should address their focus on a monitoring system. By constantly controlling the presence of testosterone in the saliva of the subjects it is possible to know when and how they are going to shift towards riskier assets. Moreover, as said before, the activation of the nucleus accumbens is another strong signal of the collective euphoria towards a specific asset. Alec Smith showed how the activation of this cerebral area leads to the creation of enormous bubbles in the market.

Bubbles, are the first cause of market insecurity and they can create global disasters mining the economic stability of the developed countries, has happened in 2008. In the short-term period, by focusing on this current knowledge and addressing our efforts to create a solid market, it should be possible to develop tools capable of partially forecast the creation of the asset bubbles and mitigate the social exuberance towards certain assets (the recent crash of Snapchat and
BitCoin should let us think). In the long-term period on the other hand it would even be possible to categorize human behaviors and reshape the laws of economics in order to contain every single possibility of human mistakes into them, to avoid even the slightest possibility of instability of the market. Great things await us in the future.
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