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A NEUROECONOMIC EXPLANATION FOR THE FINACIAL RISK MANAGEMENT FAILURE DURING CRISIS

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A NEUROECONOMIC EXPLANATION FOR THE FINACIAL RISK MANAGEMENT FAILURE DURING CRISIS

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Abstract: The scope of this paper is to explore the link among financial risk management that is heavily relied upon the science of statistics and the new upcoming models of neuroeconomics. In other words, indecision is originated by conflict and the higher the latter, the more prone to errors are investors in processing their decisions towards financial assets, independently on how well they know the probability of “success” of their investment portfolio. In sum, knowing better what originates the indecision within the decision making process it might mitigate the likelihood of giving rise to possible financial crisis as seen in 2008, since statistical models are poor in estimating out-of-sample events.

Keywords: Financial Risk Management, Neuroeconomics, Statistic models, Decision Theory

JEL Codes: G01, G14, G17, D87

1. INTRODUCTION:

Recently a growing number of researches in economics are leading towards to areas which embrace the study of rationality such as psychology, neurosciences and computer science (neural network and/or fuzzy logic). The idea is not only make economics approximate to the reality, but also try to attempt a 'creation' of an ergodic theory – stable framework –, with which it can be fallen back on continuously over time, despite an ongoing changing world.

The scope of this paper is to explore the link among financial risk management that is heavily relied upon the science of statistics and the new upcoming models of neuroeconomics. In other words, it is important to digress about the sources that make an individual decision to undoubtedly rest on the relation between the laws of probability and its “goodness of fit” towards an unknown future event.

However, investors are commonly faced with the fact that one asset over another might have a higher or lower than expected return in the future according to a determined statistical model (independently of being frequentist or Bayesian approach). Balancing out the inherited risk between both instruments originates a conflict and when the latter is high, investors are confronted with a dubious sentiment of possible gaining or losing, given rising to the so well-known uncertainty: “Should I really invest on this asset in next forthcoming days, months or years?”. This conflict induced uncertainty about deciding and it is called here indecision.

Indecision then is not exactly linked with the statistical per se, but it is a consequence of a conflict that stems from the future benefit or cost that a certain asset might bring about. That being sad, the concept of risk and indecision are not equivalent,

since the former is related to unlikely probability of a certain not to happen, whereas the latter comes from the conflict of the decision making process (of taking or not the risk). Therefore, it is indeed difficult to forecast a crisis, since practioneers focus on the statistic model rather than paying attention to the real cause of crisis - as seen in 2008 -, that is, indecision.

In the next section a brief risk historical background will be given and subsequently some aspects of statistics that helps understand the concept of risk, paying attention to some pitfalls of this approach. In section three, it will be attempted to explain the neuroeconomics model towards the idea of conflict (and thus, indecision). In fourth section, some aspects of the 2008 crisis will be explained under the neuroeconomic approach and then further caveats for future research will be exposed.

2. BRIEF RISK HISTORICAL BACKGROUND

The mastery of risk divides the past with the modern times as Berstein (1998) cited. He highlights that the origin of risk and the science of choice, that is, decision theory, are the central of modern market economy. Indeed, without the understanding of probability theory, capital markets would still be based on simple financial instruments, lacking any forward-looking vision. The 17th century was the paramount of great discoveries in natural and social sciences, especially in disciplines as economics, mathematics and physics, which, as we know today, are underpinned by problems in decision theory (the notion of utility), probability theory (law of great numbers) and mechanic statistics (calculation of orbits). From Pascal to Fermat and from Bernoulli (both uncle and nephew) to Bayes and Gauss, the advent of risk assessment shall be

granted by those unique thinkers. Their discoveries (practical and theoretically speaking) had viable the evolution of our civilisation.

As Bernstein (1998) cleverly remarked: “Without the command of probability theory and other instruments of risk management, engineers could never have designed the great bridges that span our widest rivers, homes would still be heated by fireplaces or parlor stoves, electric power utilities would not exist, polio would be still be maiming children, no airplanes would fly and space travel would be just a dream” (pg. 2). Notwithstanding those facts, economics would not know that satisfaction would be inversely proportional to any soar in quantity of goods (that is, non satiable axiom) and therefore any advance in applied microeconomics, including the modern theory of finance, would not even exist.

But one important fact about the discoveries abovementioned is the coherence between the model created through the theory of probability and one’s belief (or alternatively system of beliefs), because coherence is the source of justification and the latter is intrinsically associated to the knowledge, which makes any statistical model very close to reality, with special attention to Bayesian models. No wonder why people rely blindly on those models, as it is well-put by James Joyce [within the Oxford Handbook of Rationality (2004), pg. 132], who recognises that “beliefs come in varying gradations of strength, (...) [seeking] to replace the categorical notion of belief as an all-or-nothing attitude of accepting a proposition as true with graded conception of belief as level of confidence”.

Later on, in the beginning of 20th century, as showed in Ramsey (1931) and De Finetti (1937) and Savage (1954), Bayesianism required (as still requires) that an individual’s belief must be deemed by the following requirements,:

(1) Logical Consequence that entails the deductive logic by an assumption leading to other, must their probability as well.

(2) Bayes's Theorem which equals the conditional probability of events to the ratio of the unconditional probabilities of those events and the inverse probability of those events or also known as likelihood.

(3) Probabilistic consistency that is referred to an individual's rational subjective belief in which one of those beliefs can be represented by a probability.

In other words, the above leaves investors to attain the below characteristics: be coherent, satisfy his beliefs, and maximize his subjective expected utility. With this setting, Harry Markowitz, in 1952, claimed through the above assumptions that betting in one sole strategy is far riskier than diversifying it, created as we know today as the modern theory of portfolio selection, the basis of traditional finance theory. From this point on, this new approach triggered a financial revolution within the financial markets in the whole world. This was amplified latter with the advent of William Sharp's Capital Asset Price Model (CAPM), which remains nowadays very popular among practitioners. According to them, the advantage of this model is the easy implementation to determine the appropriate rate of return of an asset vis-à-vis a current diversified portfolio. The model takes into account the upside of an asset against a systematic risk or overall market risk, represented by the beta (β) within a determined industry, as well as the expected return of the market and the expected return of a theoretical risk-free asset, usually an interest rate practiced within an economy, such as Fed funds. CAPM allies not only portfolio selection (as advocated by Markowitz), but also the risk embedded in the market and shows how to mitigate it according to investor's strategy.

In other words, the model is based on two main assumptions: 1) Investors estimates the asset's correlations, expected return and inherent risks correctly so as to optimise the current portfolio; 2) Investors acts rationally in order to match demand and supply for those assets and therefore they are risk-averse agents.

Two decades later Eugene Fama (1967) comes up with his efficient markets hypothesis (EMH), whereby markets whose prices reflect all the available information are deemed to be efficient. Basically, rational agents do not consistently achieve higher returns *ad infinitum* (or on contrary, lower returns) above (below) average market returns on a risk-adjusted basis, given all information publicly available at the time portfolio selection is decided. Thus, markets' return tend to be mean-reverse and, most importantly, risk is a well-known, predictable variable.

Those three discoveries are the paramount of today's modern financial theory as opposed to behavioural approach. In addition to that, the evolution of computational apparatus, finance practitioners manage to apply statistically complicated models (based on the abovementioned hypothesis) to solve for possible risk events. Indeed, risk management turned out to be in the last decades a purely mathematical / statistical department. In the next section it will be exposed the main models applied in this are.

3. CURRENT RISK MANAGING MODELS

In general risks are sorted out according to its nature, that is, credit risk (i.e, liquidity risk), market risk (i.e., interest rate risk), and operational risk (i.e, systemic risk). Financial institutions use risk modelling to assess the amount of capital reserves so as to maintain (or not) its portfolio, and give some guidance on their future buys and sells of different classes of financial instruments. Each category has its specificity and they

mostly apply statistical and/or mathematical models with previous section premises, that is, expected utility maximization and fully rational agents.

Most common techniques used to model risk are: 1) Value at Risk (VaR), 2) Historical Simulation (HS), and 3) Extreme Value Theory (EVT). They are the substrate to analyse a portfolio and its likelihood of losing, given worse case scenarios assumptions.

The Value at Risk, commonly known as VaR, is defined as a threshold value, that is, given a certain level of significance (usually 90%, 95% or 99% in certain cases), what is the exact probability that the mark-to-market (MTM) loss on a certain portfolio over a given time horizon can exceed this threshold value; assuming normal markets and no trading in the portfolio.

VaR is considered to be a system, not just a number, since it is disclosed as :

$$VaR_{\alpha} = \inf \{l \in \Re / F_L(l) > \alpha\}$$

Where alpha (α) is the level of confidence of the portfolio and that $F_L(l)$ is assumed to have a normal or t-student distribution (since the latter have fat tails). The VaR is normally run in a daily basis in order to be compared to the actual price movement in the next day opening positions. This fact is validated by a back-test. Market practices to VaR system are categorised under three regimes:

A) Normal Occurrences: VaR is run one to three times in a given period (normally in a daily basis) and is expected periodic threshold breaks, since markets could behave abnormally. The hypothesis under this regime is that the loss distribution usually has fat tails and increases the error-type II, not reject a hypothesis when it may be false, since it

augments the area of “unlikely” events might occur, that is, probability of happening might be considered in a certain time horizon.

B) Stress Testing: VaR is computed from three to ten times. Institutions should be aware of all the possible events that might trigger great losses and be prepared to overcome them. Under Monte Carlo simulations, these events are deemed to be rare and then probabilities can be highly reliably.

C) Extreme Values Test: Above ten times run VaR, it would be normally wise to hedge or insure the current practice/ business.

Now turning to historical simulation, this is a computationally easy method to measure risk that takes into account a constructed cumulative distribution function (CDF) of assets' returns over a defined time horizon. It is a non-parametric procedure, since it does not assume any distribution on these returns.

On the other hand, extreme value theory is the limiting distributions for the minimum (inf.) or the maximum (sup.) of a very large collection of independent random variables, stocks' return, from the same distribution, which are generated by either full range dataset or when it surpasses a certain threshold, called peak over threshold models (POT). As Gumbel (1958) showed, for any well-behaved initial distribution, that is, $F(x)$ is continuous and has an inverse, only a few models are needed and also if the observations are bounded from above or from below.

From a regulatory standpoint, formal risk management was ratified under the Basel II Accord, where creates an international standard regulation to safeguard the international financial system from lack of capital due to leverage, liquidity issues, or even systemic / operational risk that could threaten major banks to collapse. This was attempted by setting up risk and capital management requirements designed to ensure that a bank holds capital reserves appropriate to the risk it is exposed through its lending

and investment practices. From a three pillars concept - minimum capital requirements, supervisory review and market discipline, the first one embraces risk management approach – market, credit, and operational risks – suggesting the use of VaR for the first one.

Having said that, even regulators bought the idea of applying statistical / mathematical complex models would minimize the risk of a crisis. In 2008, this regulation came to scrutiny because it failed to alert regulators to the sub-prime crisis, which contaminated other countries and created the biggest crisis the world has ever seen. In the following section, some criticism will be set out under the new behavioural finance standpoint for relying heavily on statistics and mathematics.

4. BEHAVIOURAL FINANCE AS A PLAUSIBLE ALTERNATIVE

As was seen in 2008's crisis, low frequent – high impact events can not be fully disdained by financial practitioners, since it can cause catastrophic consequences. Some problems on relying on purely statistical / mathematical models are regards to the difficulty in determining trustful probability distribution since data is scarce (human kind watched few crisis and each one had different magnitudes). Additionally, current models have unrealistic assumptions such as normal / t-student distributions of events and fully predictability of risks and parametric behaviours. This type of infrequency can cause risk managers to succumb their perception and anchor their estimations on recent / quasi-similar events, resulting in possible under appreciated consequences.

Another aspect of financial institutions is to blindly believe in the risk managers' model premises and their predictive abilities (given past experiences and academic achievements – the so called “quants”), hampering any type of learning. This usually

happens because there is a false sensation of control, where risk can be both fully identified and therefore avoided, and knowledge is mistaken with familiarity. This fact highlights the underestimation of costs (crisis is a heavy burden to pay) and overestimation of benefits. Overconfidence does not balance out the costs and benefits of a strategy, since those are already known to the investors, that is, a cognitive bias. The conflict between these two variables, cost and benefit, is completely ignored. Also, since models are similar across industry, recommendation for risk mitigation is also equal and therefore there is a fallible herding behaviour. As seen in 2008, everyone moved to one side, culminating in the explosion of the bubble assets.

Overall perception, emotion and attention are not taken into account in those models and might put in jeopardy any institutions who rests upon on myopic behaviour of risk managers and regulations which failed to address any upcoming risks. It then proposed a new model that might mitigate appropriately the risk in the subsequent section.

5. SOME FURTHER COMMENTS ON CURRENT RISK MODELLING

APPROACH

From the previous discussion, it may be said that the actual stock market behaviour is in sharp contrast with the academic models for financial decision-making such as the Theory of Market Efficiency, the Modern Theory of Portfolio Allocation, etc. (Block and Hirt, 2000; Melicher and Norton, 2007) that do not provide an adequate modelling of the large stock prices oscillations. Behavioural Finance is showing that current finance theories so far interpret the market as reflecting actions taken by rational managers in response to irrationality on the part of investors (Barberis and Thaller, 2005).

Investors are not always rational in their financial decisions (e.g., Kuhen and Knutson, 2005; Felnner and Maciejovsky ; Sanfey et al, 2006; Huettel et al, 2006), that is, they do not always try to maximize their profits (Sanfey et al, 2006). The role played by emotion in decision-making is proposed to explain the irrationality of the investors decision (e.g., Bernenhim and Rangel, 2004; Camerer et al, 2005; Loewenstein et al., 2001). It has being proposed (e.g. Kahneman and Tversky, 1979) that investors are risk seeking in case of losses and risk avoiding in case of gains. As a matter of fact, it is a Darwinian rule of evolution that the chances of survival of any animal it linked to his ability to obtain more energy from food than the energetic cost of obtaining it. Nature shaped animals to be profit seeking and risk or loss avoiding.

The evolution of brain mapping techniques in the last decades paved the way for investigating the brain activity associated with human decision-making, and neuroeconomics started as a multidisciplinary endeavour aiming to apply Neuroscience technology and knowledge to investigate and better understand models and theories proposed by economists (e.g., Gehring and Willoughby, 2002; Huettel, et al, 2006; King-Casas et al, 2005; KuhnenAnd Knuston, 2005; Knutson et al, 2003; O'Doherty et al, 2001; Preuschoff, Bossaerts and Quartz, 2006; Rocha, Rocha and Massad, 2009; Sanfey et al, 2006; Tobler et al, 2007; Vorhold et al, 2007).

Tremblay and Schultz (1999) delivered three types of juices to thirsty monkeys and recorded frontal-orbital neurons that encoded juice preference and proposed that these neurons encoded the relative juice utility. However, Padoa-Schioppa and Assad (2006) have shown that other neurons in the frontal-orbital cortex encode the cardinal utility of the juices offered to their thirsty monkeys. Multiple representations of value exist in the primate brain (Plat and Padoa-Schioppa, 2009) such that absolute and relative utilities are handled by different neurons and dependent on learning. Experience allows cardinal

utility to be engraved in brain, whereas relative preferences anchored on previous knowledge or established rules are used in uncertain environment or conditions. Seymour and McClure (2008) recently reviewed the Neuroeconomic literature that it is showing that people are very susceptible to manipulation of their price expectancies and evaluations whenever experience did not fixed cardinal utility evaluation.

The uncertainty of the financial market about the true value of a stock (s_i) turns the investors dependent on relative price evaluation of s_i anchored on the previous history of its price variation. In this context, we propose that the *closing price* of the stock a_i shall be anchored in the proposed *selling* and *buying prices* offers, which in turn are anchored on the history of the *closing price* in the previous trading.

Rocha et al (2009) proposed a neuroeconomic decision-making model based on the hypothesis that decision-making is dependent on the evaluation of expected rewards and risks assessed simultaneously in two decision spaces: the personal (PDS) and the interpersonal decision spaces (IDS). Motivation to act is triggered by necessities identified in PDS or IDS. The *adequacy* of an action (e.g., buying an stock s_i) in fulfilling a given necessity (e.g., saving money for retiring) is assumed to be dependent on the expected *reward* and *risk* evaluated in both PDS (savings for one self) and IDS (savings for the family). *Conflict* generated by expected reward and risk influences the *easiness* (cognitive effort) and the future perspective of the decision-making (short versus long term investment). Finally, the *willingness to act* (sell or buy the stock s_i) and *willingness to not act* is proposed to be a function of the expected *reward* and *risk* associated to s_i , and *adequacy* and *easiness* of the decision-making about selling or buying the stock s_i .

The purpose of the present paper is to discuss that financial decision making according to neuroeconomics involves uncertainty about deciding (or indecision about deciding) as an important issue that turns statistical models of decision making of almost of no help to describe financial crisis and so they are of no help to guide the investors in conditions of increasing risks. To accomplish this purpose, the neuroeconomic model of decision making proposed by Rocha et al (2009;2011) is summarized here, and used to show that the stock trading always involve indecision about selling or buying that turns probability assessment prone to increasing errors during financial crisis.

6. THE MODEL

In a first approximation it may be assumed that the willingness to act (to implement the action a_i of selling or buying the stock s_i) increases as the expected reward surpasses the expected risk ($benefit > risk$), and the willingness not to act (to not implement the action a_i) increases when the opposite ($benefit < risk$) is true.

6.1 CONFLICT AND TIME ALLOCATION IN DECISION MAKING PROCESS

However, as the estimated values of reward and risk become similar ($benefit \approx risk$), the conflict for deciding about a_i increases toward 1 and makes the decision hard. In addition, this conflict decreases as either expected or expected risk moves toward zero, easing the decision-making. In other words:

$$conflict = \omega_c * benefit * risk \quad 0 < \omega_c < 4 \quad (1)$$

Such that conflict decreases as benefit and/or risk tends to zero and tends to $\omega_c / 4$ if risk and benefit approaches towards 1. In this context, conflict has values varying from 0 to $\omega_c / 4$ ($0 \leq conflict < 1$) and the actual value of ω_c sets how the individual evaluates stress. High values of ω_c characterizes people that are stress prone and low values of ω_c characterizes people that are stress resistant. The study of a possible correlation between the actual value of ω_c and the level of stress hormones may be an interesting work to be done in the future.

Rocha et al (2009) proposed that the cognitive effort for deciding about a_i depends on the conflict for deciding about a_i (Botvinick, Cohen and Carter, 2004). For the sake of simplicity, here, it is proposed that:

$$cognitive\ effort = conflict \quad (2)$$

In addition, the *easiness* for deciding for deciding about is calculated as:

$$easiness\ for\ deciding = 1 - \omega_c * conflict \quad (3)$$

Two aspects of future thinking influences decision making (Fellow and Farah, 2005): 1) how steeply rewards are devalued as their delivery is pushed into the future, a phenomenon known as temporal discounting, and 2) the perceived dimensions of future time, sometimes labeled ‘future time perspective’. Although these two aspects of future

thinking seem similar, they are not equivalent. Future time perspective measures a spontaneously chosen time horizon, which would not necessarily affect the way a person evaluates an event at a specific time in the future when explicitly cued to do so. Similarly, the rate at which reward decays across a specified delay may differ across individuals even if they have a similar future time perspective (Fellows and Farah, 2005). Here, the possible time allocation (or future perspective) for deciding about a_i is assumed to be dependent on the easiness ($e_{a_i}(t)$) of the decision making. In other words:

$$\text{time allocation} = \text{initial time allocation} - \omega_t * \text{easiness for deciding}, \omega_t \geq 1 \quad (4)$$

In this context, impulsivity is characterized by low time allocation values ($\text{time allocation} < \text{initial time allocation}$) that result whenever ω_e in equation 2 is smaller than or equal to 1 and increases the easiness for deciding about a_i . In contrast, procrastination is characterized by large time allocation values ($\text{time allocation} > \text{initial time allocation}$) result whenever ω_e in equation 2 is greater than 1 and increases the uneasiness for deciding about a_i . In addition, self-discipline is characterized by more defined and stable time allocations values ($\text{time allocation} \cong \text{initial time allocation}$) that result whenever ω_e in equation 2 tends to 1 and decision is difficult because conflict is high, therefore making the easiness of decision to approach zero.

6.2 ACTION ADEQUACY

Adequacy of the action a_i is proposed to be dependent of the risk/benefit ratio, such that adequacy increases as benefits become greater than risks, and decreases otherwise. Different people have different tolerance to risks, some are risk seeking while others are risk avoiding. Rocha et al (2009) proposed to calculate the adequacy of an action a_i as follows:

$$\text{adequacy} = 1 - \frac{\omega_a * \text{risk}}{\text{benefit} + \text{risk}} \quad (3)$$

where the actual value of ω_a quantifies the amount of risk tolerance. Risk avoidance evaluations are characterized whenever $\omega_a > 1$; risk seeking evaluations are characterized whenever $\omega_a < 1$, whereas risk neutral evaluations are characterized by $\omega_a \approx 1$.

In the case of risk neutral decisions, adequacy increases as benefits increases concerning the risks of implementing the action a_i , and decreases otherwise. In the case of risk seeking decisions, the same adequacy is calculated for risks that are higher as ω_a decreases. In contrast, the case of risk avoiding decisions, adequacy decreases for the same risk evaluation as ω_a increases.

6.3 WILLIANGNESS EVALUATION

Now, the following may be proposed (Rocha et al, 2009):

1) the *willingness to implement* action a_i increases with the *expected benefit*, the *adequacy* of acting and the *time allocation* for deciding about acting:

$$\text{willingness to act} = \text{benefit} * \text{time allocation} * \text{adequacy} \quad (5a)$$

such that willingness to act increases as the action's expected benefit and adequacy increases while time allocation is maintained invariant and greater than 0. Time allocation, therefore, defines a future perspective of action implementation after that the willingness to implement a_i decreases to zero.

2) the *willingness to avoid implementing* action a_i increases with the *calculated cost* and *time allocation* and decreases with the *adequacy* of a_i :

$$\text{willingness not to act} = \text{risk} * \text{time allocation} / \text{adequacy} \quad (5b)$$

Such that willingness not to act increases as the action's expected risk and adequacy increases while time allocation is maintained invariant and greater than 0. Time allocation, therefore, defines a future perspective of action implementation after that the willingness to not implement a_i decreases to zero.

Because time allocation sets a temporal limit to the decision about implementing or not the action a_i to be made, willingness to act and willing not to act are not orthogonal evaluations, that is:

$$\text{willingness to act} + \text{willing not to act} \leq 1 \quad (5c)$$

6.4 THE POSSIBILITY OF BUYING OR SELLING

In this context, the *possibility of implementing* the action a_i (buying or selling a stock s_i) and the *possibility of not implementing* the action a_i (not buying or not selling a stock s_i) were obtained as:

$$\text{possibility of acting} = \frac{\text{willingness to act}}{\text{willingness to act} + \text{willing not to act}} \times (1 - \text{conflict}) \quad (6a)$$

$$\text{possibility of not acting} = \frac{\text{willingness not to act}}{\text{willingness to act} + \text{willing not to act}} \times (1 - \text{conflict}) \quad (6b)$$

and

$$\text{indecision about acting} = (1 - \text{conflict}) \quad (6c)$$

such that

$$\text{possibility of acting} + \text{possibility of not acting} + \text{indecision about acting} = 1 \quad (6d)$$

In this context,

$$\text{possibility of acting} + \text{possibility of not acting} = 1 \quad (6f)$$

only in the case of very easy decision makings where either benefit or risk are very low or in the case of stress resistant decision makers for which ω_c in equation 1 approaches zero. Therefore, it may be proposed that the action a_i will be implemented

if possibility of acting > possibility of not acting that is to say if the expected reward > 0.5 and the expected risk < 0.5.

7. FURTHER CAVEATS

Now let a financial engineer to be in charge of observing a group of investors deciding about selling or buying a set S of stocks S_i composing a portfolio in order to statistically model its profitability. At least liquidity and market / operational risk are fundamentally dependent on human decision about selling or buying S_i . Therefore, they are governed by the process modelled by equations 6. In this context, indecision introduces a bias on the financial engineer's evaluation of the probability of a stock S_i to be or not to be traded, if the time allocated by the financial engineer for observing the trade is smaller than the time allocated by the investors for deciding about the trade. In this case, the probability of not buying or selling the stock S_i will be overvalued and the probability of buying or selling the stock S_i will be undervalued. Besides, this error increases as the estimated values of benefit and cost of S_i become similar, either because the expected benefit decreases or the calculated cost increases.

In this context, the estimated probabilities of trading or not trading are correlated as bellow:

$$\text{probability of acting} + \text{probability of not acting} + \text{error} = 1 \quad (7)$$

$$\text{error} = \kappa * \text{conflict} \quad (8)$$

Therefore

$$\text{If } \frac{risk}{benefit} \rightarrow 0 \text{ then error} = \kappa * \text{conflict} \rightarrow 0, \text{ otherwise error} = \kappa * \text{conflict} \rightarrow \frac{\omega}{4} \quad (9)$$

As a consequence, in normal market conditions

$$\text{probability of acting} + \text{probability of not acting} \rightarrow 1 \text{ because } \frac{risk}{benefit} \rightarrow 0 \quad (10)$$

In contrast, preceding and during financial crisis

$$\text{probability of acting} + \text{probability of not acting} < 1 \text{ because } \frac{risk}{benefit} \rightarrow 1 \quad (11)$$

As a matter of fact, preceding and during financial crisis

$$\text{probability of acting} + \text{probability of not acting} + \frac{\omega}{4} = 1 \quad (12)$$

This is because statistical models are of almost of no use to describe market behavior preceding and during financial crisis.

8. CASE STUDY: NEW YORK STOCK EXCHANGE

From a regulatory standpoint, the risk management systems are ratified by the second Basel Accord or Basel II Agreement, which established international standards

to safeguard the international financial system over the lack of capital due to excessive leverage and to settle systemic problems and operational risks that could threaten the big banks to collapse. It is an attempt to impose requirements for risk assessment and management to ensure that banks hold capital reserves appropriate to their risk-lending practices and investments.

The crisis of 2008 put in check all these theories, questioned the misuse of probability theory for risk assessment in financial decision-making, given that the perception of risk is a subjective assessment and the probability of act or not act is influenced by the conflict generated by the assessments of benefit and risk of an asset, which determine the indecisiveness of the act. As seen previously, this indecision is not taken into account in the theory used by financial engineering for risk management and is critical in periods of crisis, which increase the risk perception.

As the risk management models do not estimate the value of “w”, they introduce a systematic error in their calculations, and those errors increase with the severity of the crisis. Those errors have been committed by credit rating agencies (or simply, rating agencies) that defined the rating (“quality”) of these derivatives created from the rating of the mortgages which were increasingly less secure. As the so-called Subprime Crisis increased the risk of those assets, the valuation errors by traditional methods increased also accordingly. Not included in the Basel II Accord, these type of errors have leveraged the financial crisis of 2008.

As the risk of conflict and intolerance increased, the uncertainty of decision has also grown and resulted in either its possible anticipation or procrastination. In the first case it's supposed to lead to impulsive buying and selling of shares by increasing the number of trades in stock markets or, in the second case, a reduction in activity on the

trading floor waiting for a better definition of market trends. In any of these conditions, it is expected that the market sentiment becomes a Bear Market defined mainly by the needs of sellers. These ideas can be tested experimentally by analyzing the relationship between the number of trading days in the business and the sales and purchases intentions as well as the conflict computed from the model proposed in this article. For this, we can define an index of market intentions as directly proportional to the conflict and desire to sell and inversely proportional to the desire to purchase, ie:

$$\text{index of intentions} = K * \frac{\text{conflict} * \text{intention of sell}}{\text{intention of purchase}} \quad (13)$$

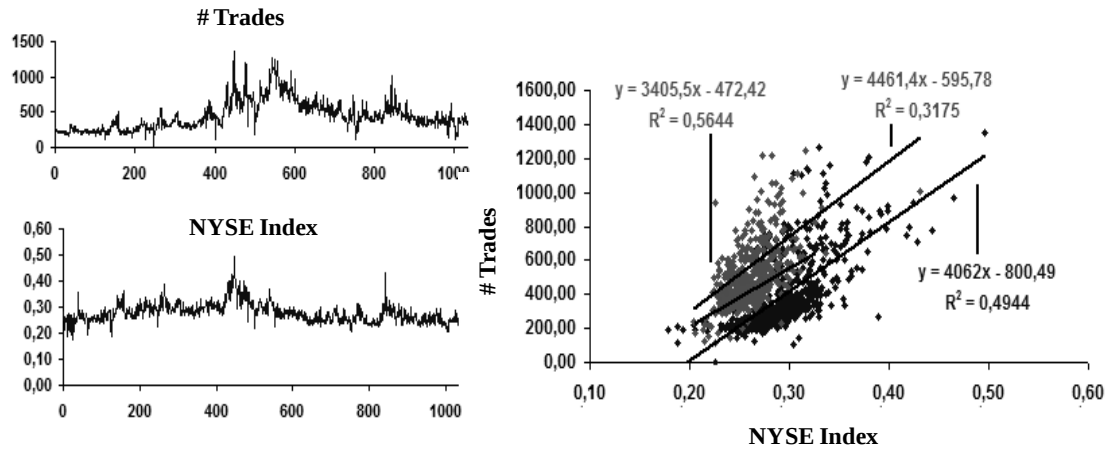


Figure 1: The evolution of business in New York trading floor (NYSE) compared the evolution of the rate of sale and purchase intentions calculated from the model proposed in this book. The regressions in the graph at right show that the correlation between business and indices was 0.49 for the period between January 2007 and March 2009, 0.56 for the period between March 2009 and May 2010 and 0.31 for the period from May 2010 until March 2011.

Figure 1 shows the evolution of the number of trades and the index of intentions for the New York Stock Exchange for the period between January 2007 and March 2011. It can be observed that the number of trades increased dramatically from September 2008 reaching a peak in March 2009, ie during the critical period of the crisis of 2008 and increases again in May 2010 during the so-called crisis of Greece. The index of intent accompanies this evolution of the business assuming maximum values in October 2008 and May 2010. Regression analysis (right graph in Figure 9-6) shows that the number of trades increases with increased rates of intentions and that this relationship is complex and can be divided into three periods:

I-) **Crisis of 2008**: the period comprised between January 2007 and March 2009, in which the correlation between business and indices, as measured by R^2 was 0.49;

II-) **Post-crisis**: between March 2009 and May 2010, in which the correlation was 0.54, and

III-) **Crisis in Greece**: the period from May 2010 until March 2011, in which the number of business stabilizes and its correlation with the intentions of the market, now also more constant, fell to 0.31.

These results seem to not only validate the model proposed in this article, but also show the possible contribution of neuroeconomics to understanding the decision-making process, and justify the continuation and expansion of this line of research studies.

9. CONCLUDING REMARKS

As Jeremy Bentham pointed out in his work “The principles of Moral and Legislation” [Bentham (2010) apud Berstein (1998), pg. 189]:

“Nature has placed mankind under the government of two sovereign masters, pain and pleasure. It is for them alone to point out what we ought to do, as well as to determine what we shall do (...) The principal of utility recognises this subjection, and assumes it for the foundation of that system, the object of which is to rear the fabric of felicity by hands of reason and law”.

In summary, it is necessary to analyse both benefits (pleasure) and costs (pain) to make a decision, knowing that the more distant these two “sovereign masters” are, the more difficult to come to a decision, since it triggers the conflict within the brain owing to unknown probabilities of the events, that is, the uncertainty / indecision.

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