Investor Behavior in Extreme Situations of Speculation and Crash: An Approach based on Iterated Prisoner's Dilemma

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***Abstract* – This paper analyzes the investor behavior in situations of speculation and crash on stock markets. The investors' main behavioral features are addressed, notably those related to cognitive and decision-making matters, in order to obtain an individual and an aggregated behavioral profile of the investor in situations of extreme events.**

Keywords: Financial Crisis, Speculative Bubbles, Investor Behavior, Rationality, Iterated Prisoner's Dilemma

1. Introduction

The complexity and dynamics of the financial markets make this matter an extremely interesting subject for analysis. More specifically, the increased instability of the markets, characterized by periods of strong speculation and by crashes, affects macroeconomic and monetary stability. This reality has led in part to a rise in related studies and therefore allowed many new hypotheses. Different proposals have been made to shed light on the dynamics of the market and its recent shape.

This is the context in which we debate investors' behavior in extreme situations in the financial market. It is demonstrated that investors can develop cooperative attitudes in a speculative period (known as bubble) so as to maintain a favorable position that brings above average benefits; in addition, their actions are flawed in more unstable situations i.e. prior to and even at the exact moment of a crash.

Firstly, a methodological approach to the problem based on considerations about investors' behavior, notably cognitive and with intellectual limitations, is presented. Then some characteristics implicit to choice in uncertainty are defined.

This involves making a brief review of the intrinsic characteristics of extreme, but real, events based specially on the market crashes of 1929 and 2000.

Finally, a game theory model is presented for the problem under analysis, departing from the assumption that investors do not make use of any type of arbitrage or hedging strategies, and their investment decisions are geared to stocks (and in bonds only to minimize the risk); the investment in other instruments, like derivatives, is only considered in the case of a strong link to stocks. It is important to note that the choice of this type of approach (game theory) is essentially due to its focus on the behavior and decisions of the players individually and in group. The impact of the dynamics and actions of players on the market where the game is played is also analyzed.

2. Some features of investor behavior

Human beings have always been the direct or indirect focus of theories in the financial and social sciences generally. Human behavior and its respective features have been a key element for the success of several models, either from a micro or macro point of view.

This has played a major role in the research into financial markets. As can be seen in the first major studies on portfolio theory, made initially by Markowitz (1952) and later by Sharpe (1962) and Ross (1976), the definition and concretization of the investor's behavior was key to the efficiency and explanatory capacity of these models.

However, the lack of accuracy demonstrated by these models in several market situations opened the way to new approaches which essentially focus on the characteristic features of the investor and his respective decisions. This has provided new possibilities to understand some events.

2.1. The Rationality postulate and the deficiencies in information processing

The rationality and consequently the processing and use of information in the decision-making process are topics that have always intrigued economic and financial researchers. The association of the proposition of rationality to the economic man, made by several theorists, has been used, across the years, as a powerful assumption in the construction of several models.

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Following this idea, it is assumed that the agent has the knowledge to make the best possible decisions in the existing environment and with the intrinsic limitations, supported by a well-organized and stable system of preferences, and in a context of perfect information, leading him to the best possible action (Simon, 1955).

It is therefore assumed that in a context of perfect information, the agent can process this information correctly and thus make the right decisions; an imperfect decision can be the result of an asymmetric information context.

However, despite the acclamation of the rationality postulate to be a vital assumption to several models, the Keynesian theory, for example, showed that good predictive models can be constructed in a way that is not based on this postulate (Blaug, 1992). As Arrow (1987: 70) refers: "*I don't know any serious derivation about the currency demand based on rational optimization*".

Therefore, an in-depth analysis of this issue is made, starting with an overview of the orthodox financial theory, followed by the ideas of the behaviorists, evolutionists and neuroeconomic theorists. The main objective is to provide an alternative theoretical background to support the non-appliance of the utilitarian agent in the subsequent model derived later on.

2.1.1. The Financial vision of Rationality

Markowitz (1952) was the first to bring a well designed approach for the selection of assets and construction of an asset portfolio to the financial theory. In his attempt to explain the allocation and selection of securities in a portfolio, he made a set of assumptions, notably the rationality principle. More specifically, it is assumed that within a context of perfect information the investor maximizes (or should maximize) the discounted expected returns, and diversifies (or should diversify) his funds among all the available securities, leading to a situation of maximum expected return and a mean-variance portfolio (Markowitz, 1952).

Some years later, the Capital Asset Pricing Model, known as CAPM, was developed in articles by William Sharpe (1964), John Lintner (1965) and Jan Mossin (1966). This model focuses on the relationship between the level of risk and the expected return of an asset and on the following and subsequent *equilibria*. The set of assumptions used is quite similar to what was used by Markowitz. All investors are rational mean-variance optimizers; hence, if all investors are rational, they will all analyze securities in the same way and share the same beliefs, which leads to homogeneous expectations (Bodie *et al*, 2009).

Another important asset pricing model is known as the Arbitrage Pricing Theory (APT) by Stephen Ross (1976). Though similar to CAPM, it is more general in the sense that the security returns are described through a factor or a set of factors related with the macroeconomic, financial or business sector environment. The main assumption is that a well-functioning security market does not allow the persistence of arbitrage opportunities because securities are not mispriced over a long period of time (Bodie *et al*, 2009; Ross, 1976).

Notwithstanding some other important models, it is turn lastly to the Efficient Market Hypothesis (EMH). Like the abovementioned assumptions, EMH assumes the market to be efficient and that individuals are rational. Basically, a market is efficient if the traded assets reflect all the available information in a given time, and if the price of the asset adjusts as quickly as possible to the new information; this leads to a random walk as the prices change unpredictably (Bodie *et al*, 2009).

2.1.2. The behaviorists critique and alternative

Despite the huge advances brought by the abovementioned theories to the evolution of financial and economic theory, they tend to fail in several situations because they are usually based on a normative analysis, which is concerned with the rational solution for the decision-making problem. This solution results from the definition of the ideal decisions to approach, rather than a descriptive analysis of the way in which real people actually make decisions (Kahneman and Riepe, 1998).

One of the critiques made by behavioral finance is that almost all investors suffer from biases of judgment and decision-making, sometimes called cognitive illusions. For this reason, the investor does not always process information correctly and tends to assume risks that do not acknowledge; this leads to incorrect probability distributions and inconsistent and systematically suboptimal decisions (Bodie *et al*, 2009; Kahneman and Riepe, 1998).

Overconfidence is one such bias. When the investor makes his own prediction, he often sets a very narrow confidence interval, thinking of specific quantities and anchoring too much in his own prediction. Unfortunately, few people are able to calibrate their predictions well and judgment errors are common. Moreover, this phenomenon is expected in dynamic environments where the agent systematically faces different problems and cannot learn with past examples as quickly as other agents in more stable environments (De Bondt, 1998; Kahneman and Riepe, 1998). If the investor is rational, the environment will be indifferent to his decision, making it well calibrated and leading to the same or similar behavior to that described in financial models.

Optimism is another important bias that supports the critique made by behavioral finance to the rationality postulate. The agent tends to rely too much on his own beliefs and talents so that he exaggerates the future outcome. Mixing optimism with overconfidence will generate an overestimation of the knowledge acquired and an underestimation of the risks, leading to an illusion of control in most events (Kahneman and Riepe, 1998; Shiller, 2000).

While these two biases are a great constraint to the investor's decision-making process, the hindsight bias can also play an important role because it encourages the agent to see the future as more predictable than it really is, and this will heighten overconfidence. If the event had been predicted, many of the bad situations would have been avoided because almost everyone would have modified their actions (Shiller, 2000).

Over-reacting to change events is another bias that is closely linked to the overconfidence phenomena. The investor believes that random moves are more likely to occur than systematic ones, impelling him to perceive patterns that do not exist; this indicates overconfidence in judgments about uncertain events (Kahneman and Riepe, 1998).

All four judgment biases are generated and amplified by certain types of anchor. In general, people tend to anchor too much because, when making ambiguous and complex decisions, they are influenced by the readily available information. The overconfidence and optimism biases may appear in situations where the investor uses quantitative anchors, e.g. the most recently remembered price or the nearest milestone to a major index. These anchors can lead to several judgment errors, creating an illusion prediction. On the other hand, moral anchors can be responsible for the hindsight bias because when the market is not working well, people tend to hold on to stories and intuitive reasons to embrace their investments and to see a more predictable world than actually exists. The fragility of these anchors lies in the agent's difficulty in using them to think ahead to contingent future decisions (De Bondt, 1998; Shiller, 2000).

Another limitation of the rational decision process is due to the heuristics used. In the original Greek definition, adopted by Duncker (1945), heuristic "serves to find out or discover" and is used to describe strategies such as "looking around" and "inspecting the problem". A few years later, Simon (1955) defined heuristics as strategies that facilitate decisions. More recently, the term has evolved, especially in the decision-making segment to denote strategies that help to find and to discover correct answers to problems in the probabilistic area of decision (Goldstein and Gigerenzer, 2002).

However, when dealing with optimizer behavior, the use of heuristics to solve problems sometimes leads to judgment errors and inefficient final outcomes. The representativeness heuristic is an example of this. In uncertain situations, a judgment is made by looking at familiar patterns and making an assumption that the future will resemble past patterns. In these cases, even without a sufficient consideration about these patterns, probabilities can be forgotten which results in overconfidence. Individuals dealing with uncertain environments such as financial markets may use this short-cut and make decision mistakes (Shiller, 2000; Tversky and Kahneman, 1974). In addition, recognition heuristic reflects a lack of information processing by the agent. It is used when the agent faces a choice between two or more objects. In these situations, the known object has a higher value in the individual's decision criteria. This heuristic relies on low cognitive ability and is often systematic. The problem focuses on the fact that the individual chooses the recognized object because he has more information about it and acting against the recognized object requires more cognitive effort (Pachur and Hertwig, 2006; Volz *et al*, 2006). Another heuristic that influences the decision-making process is known as the adjustment and anchoring heuristic. The anchoring process was examined above, but in this particularly case it is associated to the mental short cut of adjustment. In some uncertain situations, the agent estimates the final outcome, starting from a given initial value that is adjusted over time to yield the final result. Different initial or starting points obviously yield different estimations that are biased toward the initial values, in a phenomena caused by the anchoring. This problem is catalyzed essentially by insufficient adjustment and the existence of biases in the evaluation of events that are known as conjunctive (events that must occur in conjugation with others, like a multiple step plan); and disjunctive (events that are successful if at least one event is favorable) (Tversky and Kahneman, 1974).

2.1.3. Evolutionism approach

Evolutionism is another approach that represents a different way of analyzing the rationality postulate. The application of Darwin's theory of evolution to economic and social sciences has been controversial in recent years, principally because some authors consider it too mechanic and biological to be applied to the dynamics of sciences that deal with social and economic problems (Aldrich *et al*, 2007).

Despite these critiques, nowadays evolutionism is an important theory that can give a valid alternative to the rationality postulate.

The critique of the rationality postulate implied in the orthodox financial and economic theory is sustained, in the most general and simplified way, by the theory of Mayr (1988), known as paradigm of program-based behavior.

Mayr's theory essentially relies on the fact that an agent's behavior can be seen and guided by programs encoded to face different situations. These programs allow the agent to foresee and face the consequences of his potential choices in uncertain environments. These programs are constructed and mutated by a process of learning and evolution, through which they become more adapted to the relevant characteristics of given problems and environments. This process tends to eliminate and replace inadequate programs with new programs with different characteristics and knowledge in order to make decision-making more accurate. Thus, programs tend to be more adapted to the different problems and are a product of the agents' evolution and learning (Mayr, 1988; Vanberg, 2004).

The implication of this theory to this discussion relies on the possibility for specific actions to be not rational (from an optimizer way of thinking), even if programs are well adapted to the particular problem and environment. It is allowed trough this theory the possibility of the existence of a systematic account for observed behaviors that can be considered as irrational and that are classified as anomalies (Vanberg, 2004).

2.1.4. The role of emotions and the neuroeconomic analysis

The role of emotions in the decision-making process and questions related to the analysis of utilitarian rationality has received growing support in recent years. Neuroeconomics is one field that has devoted considerable effort to this area. One of the main points of research in neuroeconomics is the relation between brain activity and the choice and decision-making process under uncertain conditions. The neural reactions to some situations of choice can lead to a better understanding of how some decisions and actions are taken.

Damásio (1994) gives two examples that illustrate this problem. The first is that of Phineas Gage who lived in the mid 19th century in New England. He was a foreman working on the construction of a railroad. On a given day, when he was trying to detonate a pile of rocks, an iron bar was projected into his face, entering in the left side of his face and getting out by the top of his head. Phineas did not die and was fully conscious when he went to the hospital. Doctors today would know that this was a lesion in the Ventromedial Prefrontal Cortex and that the other important brain lobes were fully intact. Although he resumed normal life two months later, but never more was the same. The balance between the intellectual and instinctive sides had been destroyed and he became unpredictable and indecisive, displayed few emotions, made countless plans for the future which were easily abandoned. He was no longer able to work as a foreman, but the same problems arose when he did other jobs. He was unable to make decisions that were coherent with his knowledge. He died years later from a pathology known as *status epilecpticus.*

Damásio's second example is that of Elliot who had a brain tumor known as Meningioma; this was surgically treated by removing frontal lobe tissue but a lesion in the cortical region had damaged the Ventromedial Prefrontal Cortex (the temporal, occipital and pariental regions were intact, as were the basal ganglions and thalamus). Nevertheless, he made a good recovery but, like Phineas, was never the same again. He rarely got angry, and rare were the situations when he expressed emotions. This was caused by poor access to the social knowledge which is essential to more advanced reasoning. Some of the tests conducted revealed he was unable to make an efficient decision and sometimes no decision at all (Procrastination).

In these cases and others of lesions in the Ventromedial Prefrontal Cortex, patients show diminished emotional responsiveness and limited social emotions, closely associated to moral values. They also sometimes exhibit above average tolerance to anger and frustration which generally lead to bad or inefficient decisions. Notwithstanding, their general intelligence, logic reasoning and knowledge is unaffected (Koenigs *et al*, 2007).

This profile of a VMPC (Ventromedial Prefrontal Cortex) patient can be explained by Damásio's Somatic Marker (1994). In cases of decision-making which require the evaluation of future consequences, the somatic marker classifies the future action as good or bad. The somatic state makes the decisions quicker and more effective. Lesions to the Ventromedial Prefrontal Cortex cause the somatic signals guiding the action to fails. As a result, patients show indifference to possible future consequences of their actions, and are unable to see beyond the present. (Butman and Allegri, 2001; Damásio, 1994)

According to some empirical studies by Bechara *et al* (1994, 1996 and 1997), and Koenigs *et al* (2007), the main conclusion, is that VMPC patients have more utilitarian judgments and act more according to the economic and financial doctrine of rationality although may not be the best strategy (because this behavior does not take into account the importance of emotions in the decision-making process). In studies using card games, VMPC patients prefer to take risks and dangerous bets without considering the future outcomes of their actions. In the study by Koenigs *et al* (2007), VMPC patients have no difficulty in taking decisions in more emotional and stressful situations, which leads to more inefficient decisions/outcomes in a utilitarian way.

It can be concluded that the emotional side plays an important role in the decision-making process, leading to more efficient choices. It is known that uncontrolled emotions can lead to irrational behavior. But the reduction of emotions can lead to equal irrationally behavior (Damásio, 1994).

If emotions are responsible for irrational and rational decisions, the individual is not fully rational. But without emotions and with an increase in the utilitarian judgment, his decisions can be equally irrational and so the rationality postulate implied in most of the models cannot be correct.

2.2. The dynamics of the investor behavior

Arriving at this point, it is appropriate to analyze the particularities of the investor in a dynamic environment, highlighting and detailing the factors that determine his behavior in the market.

In investment dynamics, many decisions are made and this process is extremely intensive and demanding. It is important to define the features that determine the process to provide a profile of the investor. Thus, a brief review over the preferences of the investor's preferences, the way he makes a choice and the determinants affecting the decision-making process will be made.

2.2.1. The vision of orthodox financial theory

In financial theory, the investor's features are part of aggregated models that try to make a macro explanation of market behavior; this implies defining a more general, and less precise, set of assumptions for the investor.

In this context, the first assumption refers to the investor's preference to smooth his consumption, because of: (1) Time Consumption and the (2) Risk Dimension. The first is based on the fact that consumption is higher than the income in the early years of active life, because of situations like purchasing a house or a car. However, during those times, savings are constituted, that will be spent after retirement when the income is zero and consumption is positive. The risk dimension factor is based on the fact that the future is uncertain and that many states of nature can occur, which in turn makes it necessary to level off consumption so that it is not excessively concentrated in potentially unfavorable periods (Danthine and Donaldson, 2005).

Based on this, the process of decision-making can be divided into situations of certainty and uncertainty. While the assumption of rationality can be accepted in a situation of certainty (with the appropriate reservations because the choice depends on the framing of the problem) with every investor having a complete preference relation and the property of transitivity in a continuous relation, this is more difficult to occur in uncertain situations. In these situations (like a lottery), it is assumed that the preference relation is complete, transitive and continuous, with an independence of irrelevant alternatives. This last assumption is not common ground because it depends, for example, on the way in which the problem is placed (framing); this will be analyzed in more detail below (Danthine and Donaldson, 2005; Huang and Litzenberger, 1988).

Another assumption is that the investor is risk-averse, because he usually wants to avoid a fair gamble (when in an uncertain environment); his utility function is concave because, as the wealth increases, the utility from the additional consumption decreases (also known as decreasing marginal utility). However, despite not being assumed directly in the portfolio theory, this degree of risk-aversion can be measured in two ways: a) in terms of absolute risk aversion (ARA), that is, sensitivity to the amount and; b) relative risk-aversion (RRA), i.e. sensitivity to the proportion of wealth at stake. Thus, it is assumed that an investor will only play a fair game if there is a certainty equivalent, i.e. if there is an amount of money that is a certain equivalent to the investment that he could make (Holt and Laury, 2002).

Assuming the above, the problem for the investor is to maximize the expected utility of his wealth allocated in the possible investments. To do so, he integrates mean-variance preferences so that when there are investments with the same mean, he chooses the one with the smaller variance, and in the case of investments with the same variance, he chooses the one with the larger mean (Markowitz, 1952).

Every investor will generally possess the market portfolio and will invest in a risk-free asset (in order to respect the two fund separation), so the wealth will be allocated between the rf (risk free asset) and the tangency portfolio. But because the investor is risk-averse, he will only invest in the risky asset if his expected return is higher than the rf (McDonald and Siegel, 1986). Then it will be respect mean-variance dominance:

$$\text{Asset a dominates asset b if } \begin{cases} \mu_a \geq \mu_b \text{ and } \vartheta_a < \vartheta_b \\ \text{or} \\ \mu_a > \mu_b \text{ and } \vartheta_a \leq \vartheta_b \end{cases} \quad (1)$$

Moreover, he will look for changes in the composition of the portfolio in terms of the correlation; this implies that the construction of the portfolio will mainly take securities that have a correlation of between]-1;1[into consideration (Bodie *et al*, 2009; Markowitz, 1952).

It is assumed that a more risk-averse investor will allocate less wealth on the stock market; however, this sometimes depends on the intrinsic utility function of the investor.

Also, according to the CAPM, all investors possess the market portfolio and will therefore be pleased when the market goes up and sorrowful when it goes down; because they respect the law of decreasing marginal utility. This implies that what really matters to the investor is getting additional good payoffs in bad circumstances (of low market returns), which in turn makes the investor less enthusiastic about additional payoffs in good times. It can therefore be concluded that the investors like assets with low covariance with the market (Bodie *et al*, 2009).

2.2.2. An alternative based on Behavioral Economics and Finance

(a) Hyperbolic Discounting

Most decisions made by an investor involve a trade-off between outcomes/choices that will have effects on different periods; which in the real markets imply that the investor has to decide between investment options that may be more valuable in the future than in the present. This relation is captured in a conventional analysis by a discount function. With the help of this instrument, it is possible to measure the utility obtained from a series of future consumption situations, occurring at regular intervals, leading to the calculation of a Discounted Utility Function.

$$U' = \sum_{d=0}^{n} F(d)\, u\big(c(t+d)\big) \quad (2)$$

Where *F(d)* is the discount function, *t* the time of evaluation and *c(t+d)* the resources consumed at time *t+d*.

Thus, the discount function is a declining function of delay and often given by a discount rate *r*, which is the proportional change in the value of *F(d)* over a standard time period. It is also important to note that the decision maker is impatient and the rate of change of

F(d) is the pure rate of time preference. In addition, for rational decision makers, the rate in which money should be discounted must equal their marginal rate of substitution between the present and the future to the market interest rate.

Taking the following example: if we actually prefer 5€ in 3 months to 4€ in 2 months, then in 2 months time we will prefer the 5€ in 1 month to 4€ immediately unless there is a sudden need for cash. However, this may not occur with certainty and can imply an inconsistent time preference. Taking the examples given by Ainslie (1975), Ainslie (1991) and Read (2003) where we have a choice between two alternatives: a smaller-sooner (X) and a larger-later (Y); while the larger-later alternative is preferred when both are substantially delayed, when smaller-sooner alternative becomes imminent it undergoes a rapid increase in value and is briefly preferred. For example, the smaller-sooner reward can be the pleasure from a cigarette and the larger-later reward might be good health. The prospect of good health is preferred when looking one week ahead, but the desire for the cigarette grows faster than the desire for good health as time passes, until, for what may be a very brief period, the cigarette is preferred.

This kind of situation makes it difficult for the agent to plan the future and stick to it, which degenerates into procrastination. This example also shows that the discount rate does not always change proportionally to the value of *F(d)* over a standard time period like the one referred. Due to these time inconsistencies, a hyperbolic discount function can be the best way to illustrate this type of behaviour, instead of exponential discount functions as assumed when the decision maker is a rational agent, because it considers there may be a brief and temporary reversal in preferences (Read, 2003).It can therefore be said that individuals do not always smooth their consumption because, at one point in time, the agent may reverse his preferences (Steel and König, 2006).

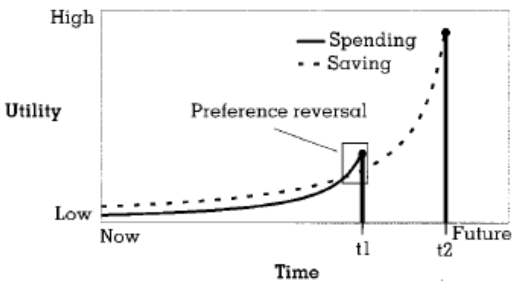

Figure 1: Possibility of reversal of preferences (Steel and König, 2006)

Another point that is not consensual is the consideration that money should be discounted at the prevailing market rate (Thaler, 1981). In fact, people do not apply the same rate to all decisions, being instead this rate highly domain dependent and even in the domain context dependent from the choice context (Chapman and Elstein, 1995). In addition to time inconsistency, several anomalies, linked to the constant discount theory can be summarized:

- **Delay effect**: if we elicit the present-value of a delayed outcome or the future value of an immediate outcome, then the longer the delay, the larger the obtained value of the discounting factor (Read, 2003);
- **Interval effect**: The difference between the delays of two outcomes is the interval between them. So discounting depends heavily on the length of this interval, in that longer intervals lead to smaller discount rates or larger discount functions (Read, 2001);
- **Magnitude effect**: This means that the discount rate is higher for smaller amounts (Green *et al*, 1997; Read, 2003; Shelley, 1993);
- **Direction effect**: the discount rate obtained by increasing the delay of an outcome is greater than that of reducing that same delay (Loewenstein, 1988; Read 2003);
- **Sign effect**: The discount rate is lower for losses than for gains (Antonides and Wunderink, 2001; Thaler, 1981);
- **Sequence effects**: A sequence is a set of dated outcomes all of which are expected to occur, such as one's salary or mortgage payments. People usually prefer constant or increasing sequences to decreasing ones, even when the total amount in the sequence is held constant (Chapman, 1996);

(b) Prospect Theory

For orthodox financial theory, the evaluation of outcomes and the decision-making process can be analyzed by taking the expected utility theory into consideration. In this theory, it is assumed that investors attempt to maximize the expected utility of their choices between risky options, giving weight to each outcome according to their probability and choosing the one with the highest weighted sum (Luce and Raiffa, 1952). It is also assumed that the psychological value of money or goods follows the rule of diminishing marginal utility, which is represented by a concave utility function, implying the presence of risk aversion (Levy, 1992).

Prospect Theory however posits a different way of analyzing this problem. It is assumed that the agents evaluate outcomes based on the deviations from a given reference point, instead of the level of net assets or value. The real deal, however, is the identification of this reference point. At the moment zero, it is usually assumed to be the *status quo*, but in some other cases it may be the aspiration level or another point. Allied to this, the agent is not always risk-averse and this varies depending on whether we are dealing with gains or losses (Kahneman and Tversky, 1979).

For example, an experiment by Kahneman and Tversky (1979) gave the choice of a certain outcome of $ 3000 vs. 80% chance of winning $ 4000 and 20%

chance of winning nothing. 80% of the respondents chose the certain outcome. However, when dealing with the same problem but in a negative frame, 92% chose to gamble when there was 80% chance of losing $ 4000 and 20% of losing nothing to a certain loss of $ 3000. In both cases the option with the lower expected value was chosen, which is incoherent with the expected utility theory and highlights the risk profiles. It suggests that individual utility functions are concave for the domain of gains and convex for the domain of losses; this is a pattern known as the reflection effect to the reference point. This implies that the sensitivity to changes in assets decreases as one moves further in either direction from the reference point (Kahneman and Tversky, 1979; Laury and Holt, 2000).

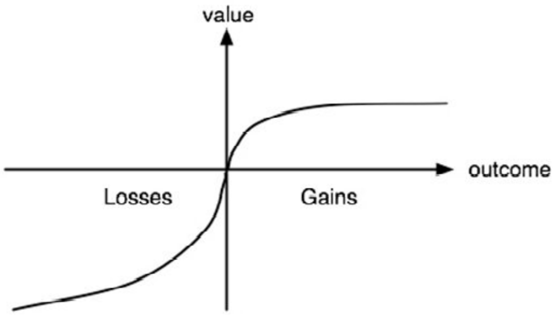

Figure 2: Prospect Theory utility function (Kahneman and Tversky, 1979)

However, the previous example shows that the propensity for risk depends on the way in which the problem is placed, i.e. the way it is framed. For example, in Kahneman (2002), to subjects were given the hypothetical choice between programs to outbreak a disease which was expected to kill 600 people. On the first attempt: program A corresponded to 200 people saved while in program B there was a 1/3 chance that 600 people would be saved (and no one die) and 2/3 that no people would be saved. On a second attempt: program A implied the death of 400 people and program B corresponded to a chance of 1/3 of people not dying and a 2/3 probability of people dying. The results showed that on the first attempt the majority of respondents chose program A, which indicates risk aversion. However, on the second attempt, program B was mainly chosen, which indicates risk-seeking behavior. It can be concluded that on the first attempt the possibility of certainly saving people was more attractive than a probability; on the other hand, respondents were averse to accepting the certain death of people and thus sought more risky alternatives (Kahneman, 2002).

Allied to this context, there are two types of effect that influence the decision-making process. First, the certainty effect, which impels the individuals to overweight outcomes which are certain relatively to outcomes that are merely probable. Also, they overweight low probabilities and underweight moderate or high probabilities. The latter effect is more pronounced. Therefore, extremely likely but uncertain outcomes are often treated as if they were certain; this is known as the pseudocertainty effect (Levy, 1992). Also changes on probabilities near to 0 or 1 have a greater impact on preferences than comparable changes in the middle probability range, leading to behaviors of subproportionality (Tversky and Kahneman, 1986).

(c) Mental Accounting

The mental accounting theory has proven to be a partially effective and efficient approach, along with the prospect theory, to understand the behaviour of agents and particularly of investors. For Kahneman and Tversky (1984), mental accounting is an outcome frame which specifies a set of elementary outcomes that are evaluated jointly and the manner in which they are combined; it is a reference outcome that is considered neutral or normal. It supports three important features: the prospect theory value function over gains and losses is used in relation to a reference point; both gain and loss functions display diminishing sensitivity; at the initial reference point (*status quo*) the agent is risk averse (Thaler, 1999).

One of the main proposals of this theory is that people behave according to the hedonic framing proposition, i.e. they segregate gains and integrate losses (because the respective functions are concave and convex) and more specifically, integrate smaller losses with larger gains and segregate small gains from larger losses (Thaler, 1985; Thaler, 1999). However, this proposition can sometimes fail, principally for the integration of losses, as Thaler and Johnson (1990) showed in their research. People sometimes think it is good to integrate losses, which intuitively implies that it should diminish the marginal impact and suggests that a prior loss makes them more sensitive to subsequent losses (Thaler, 1999).

Mental accounting therefore predicts that, if for example, we buy, *s* stocks at *p* price, the investment will initially be worth *[s * p]* and will fluctuate in accordance with the evolution of stocks on the market. In fact, even with changes over time, which implies theoretical gains or losses, it only becomes a realized gain or loss when this position it is sold. An account will be opened with *[s * p]* and will be closed with the realized result, which can compensate or not for the initial investment. But because closing an account at a loss is painful to the investor, the prediction of mental accounting is that investors will be reluctant to sell securities that have declined in value. If at a given moment the investor has a need for cash, he will look at his asset portfolio (which for example contains *n* securities) and will sell those with a higher value than at the time of purchase. However, this hypothesis contradicts a rational analysis that postulates that the investor should sell the securities that were lower than their initial value. However, the assumption made by mental accounting theory can be supported on the example of Odean (1998) that, using data from transactions made by a big brokerage firm, had show that investors were more willing to sell one of their stocks that had increased in value than one that had decreased.

Another particularity analyzed by mental accounting is that sometimes the investor suffers from behaviour termed myopic loss aversion. This behaviour is analyzed in detail in the Equity Premium Puzzle of Benartzi and Thaler (1995); it focuses on the difference in the rate of return of equities and a safe investment like treasury bills, which historically has been very large (6% in the USA in the past 70 years) and which resulted in the appreciation of 1 dollar invested in equities almost 120 times the return from the dollar invested in treasury bills. However, T-Bills was the primary destination for investment in these years. The explanation for this puzzle was that the investor's loss aversion is strictly dependent on the frequency with which he reset his reference point (or how often he counts his money). The result was that people are indifferent as to investing in stocks or T-Bills if they only evaluate changes in their portfolio every 13 months. So the investor can suffer from myopic loss aversion because this myopic behaviour prevents him from using the best long term strategy and makes him think primarily about the present; which makes him evaluate the composition of the portfolio with great frequency. When the evaluation period is larger, the attractiveness of stocks increases (Thaler *et al*, 1997; Thaler, 1999).

3. The anatomy and history of Bubbles and Crashes

Bubbles and Crashes are unique situations which have been studied across the years. Economic and financial theorists' interest in this theme may be due to the fact that almost all propositions about investor rationality and then market rationality can be violated. Thus, in relation to the present article, a more realistic and improved investor profile can be constructed using this kind of situation because the efficient market hypothesis loses its descriptive validity.

According to the efficient market hypothesis, a crash occurs when a dramatic piece of information is revealed. However, this approach can be considered reductive as the piece of information that triggered the problem may be unknown; even when known, a period must have preceded the crash that created the necessary conditions.

In contrast with the market efficient hypothesis, it can be said that in these situations the market has entered an unstable phase so a small endogenous disturbance is sometimes enough, to trigger a shock (Sornette, 2003). The 1929 and 2000 crashes can be used to describe such unstable phase; in these years, the preview upward trend in stock prices never more was seen, being replaced by an unstable and undetermined fluctuation, with special emphasis on losses.

In fact, this situation is preceded by a rapid rise in market prices, known as a bubble, created by growing interaction and cooperation between investors that can last for months and even years. Investors are unaware of the cooperation relations that result from a general belief in a new state of affairs, triggered primarily by the growth of a given sector or industry. The expectations and beliefs generated tend to be accepted by the group of investors, which helps prices rise quickly and vertically in some days (Galbraith, 1954; Kindleberger *et al*, 2005; Sornette, 2003).

It can be concluded that the market's unstable position will lead to a collapse and the piece of information that trigged the reaction can be considered secondary (Sornette, 2003).

It will be now present a brief review of some historical stock market crashes to introduce the problem analyzed with the Iterated Prisoner's Dilemma.

However, the following criteria were used to select these historical events.

- First, these events took place in the United States of America. Despite the globalization on the financial markets, there are cultural, social and other differences between investors in different countries and these can lead to singular behaviors and practices that could skew the analysis.
- Second, these extreme events were primarily in the stock market. Events that originated in other security markets were excluded.
- Third, these events were preceded by long periods of speculation and formation of a bubble, followed by very destructive crash. This explains why Black Monday of 1987 is not in the list.

Two stock market crashes were chosen: The Great Crash of 1929 and the Dot-Com Crash of 2000. Both represent an optimal context of Bubble and Crash, meeting the above criteria. Both have long periods of speculation and strong crashes. The expectations and behavior of investors were quite similar, despite the industry or sector that leaded these beliefs.

The financial crisis of 2008 was not chosen, because it can be assumed that Financial Institutions, e.g. commercial and investment banks and other financial companies, created the speculative moments and not investors. Moreover, this event originated in the real estate market and not the stock market. Finally, the effects of the crisis are still ongoing and it is difficult to dissociate the subsequent effects from the recessive macroeconomic landscape.

3.1. The Great Crash of 1929

The 1920s could be called both a golden and a dark age. With World War I at an end, everyone was convinced that this would be a prosperous decade. Indicators for economic growth and development were improving; consumption was growing at a fast pace, and the level of prices was stable.

It was the time of the American dream which foresaw a better, richer and fuller for one and all. It was a vision of a social order in which everyone could reach their maximum potential and break the barriers of the old social hierarchy (Adams, 1931).

However, in the late 1910s, the rich were becoming richer more rapidly than the poor were becoming less poor. Because of this context, the financial and real estate markets provided the opportunity to get rich with the minimum effort, thus fulfilling the American dream and inverting the trend of the previous years (Galbraith, 1954). This led to the great demand in the real estate market across the USA, particularly in Florida and should have been a forewarning of what would happen in 1929.

The problem to accomplish this desire was that individuals simply believed that they were meant to be richer, regardless of their intellectuality restrictions, that is, cognitive limitations based on limited rationality and in the use of heuristics that could bias decision. Risk-taking and irrational decisions were the order of the day. An entire industry was born to provide services to investors on the stock market such as brokerage firms, investment banks and investment trusts. The creation of a bubble was inevitable, the same for the following crash (White, 1990).

3.1.1. The premonition

In the early 1920s, the first signs of speculative behavior and irrational illusion came from the real estate market. The main boom was in residential housing (White, 1990). Between 1921 and 1925 construction grew at a rapid pace with housing prices and building costs following the same trend. The boom was fueled by good macroeconomic conditions as well as the desire to become a home owner so as fulfill the American dream. This environment led to a change in the profile of investors with preference being given to short term profit as opposed to the constitution of savings.

Florida is the most outstanding example of the boom in the real estate market. The standard of living and its transport system developed quickly and the climate made it the perfect location for a speculative wave in real estate. Investors were easily influenced at the time and simply wanted an excuse to believe in something. And that excuse and belief came from the expectation that Florida would become a dream place, full of opportunities and rich people enjoying the local conditions. In addition to the formation of positive expectations, the real estate market began to increase, making real the expectations of the investor. With time, the price of land rose and land owners were soon making big profits. After some time, the reasons for the investment on these lands started to disappear, exceeded by the possibility of easy profits. The problem arose on the beginning of 1926, when the number of new investors and houses began to fall. The subsequent decline in house prices was the beginning of a slow crash; the Great Crash of 1929 that followed dashed all hopes of recovery (Galbraith, 1953; White, 2009).

The example of Florida reflects what happened across the USA and demonstrates that Americans were driven by the desire for get-rich-quick investment opportunities in the early 1920s.

3.1.2. From the prior years to the Great Crash – Euphoria and Mania

At the beginning of the 1920s, conditions were ripe for the expansion of the stock market. Despite the good macroeconomic environment, stock prices were low and dividends reasonable. Most companies were making high profits and this seemed the prevailing trend. Some of these were new large-scale commercial and industrial enterprises that took advantage of innovative processes and technologies. They were able to capture economies of scale and scope which made their production processes very efficient. Moreover, there was a great transformation in the utility sector in large part because of the rapid growth in the modern industrial enterprises. In hindsight, high returns could not be sustained because the markets were poorly developed and companies held unbalance structures (Chandler, 1977; White, 1990).

The greatest increase in the volume and prices of the stock market, particularly in the Dow Jones Industrial Average, began in 1927. In previous years, the stock market had flourished thanks to the growing interest of investors but prices were more volatile and the volume was relatively small. The slight growth until 1925 was followed by a very volatile period in 1926 due to expectations of an unstable macroeconomic scenario, before returning to growth in 1927.

This recovery was a product of a turnaround in the macroeconomic expectations, fueled several reasons, in which stood out the decrease in half percent made by the Federal Reserve in the discount rate, which increased the demand for Government Bonds. Commercial banks and some investors who held those bonds saw this as a good opportunity to sell and transfer their funds to the stock market (Galbraith, 1954).

At the start of 1928, stock prices started rising more quickly. Just as with the real estate boom in the early 1920s, investors only needed an excuse to believe in something and at this time they were convinced the stock market would bring them great wealth with little effort. With this it started a new “gold rush”, with stocks going up 10 or 20 basis points a day, with the utility and new technologies leading the gains (Galbraith, 1954).

There was a frenzied increase in the volume of trading. In June 1928, the volume surpassed the utopian mark of 5.000.000 stocks, rising further to over 6.000.000 in November (Galbraith, 1954). Also, according to Galbraith (1954) and Allen (1931), that year sealed the beginning of the speculative bubble, more specifically in March.

Given the context of the 1920s and especially after 1927, it became evident that those investors would need support and this provided a new market to explore. Regulations of commercial banks from the 19^{th} century limited the provision of long-term loans; however, this was overcome by setting up wholly-owned securities affiliates that were allowed to enter in all aspects of the investment banking and brokerage business. On the other hand, investors without enough capital to purchase a diversified portfolio of stocks saw a new industry of services develop, namely investment trusts. New ways of investing in the stock market also emerged e.g. margin deposits and negotiation i.e. the buyer, with margin, contracted a loan to buy a given number of stocks which remained in the possession of the broker as a guaranty of the loan. The buyer benefited from any value increase and with the same and fixed loan value. Whereas the investor was anxious to invest and benefit from the constant increases in the market, this kind of service sent supplementary funds to the market (Galbraith, 1954; Sornette, 2003; White, 1990).

3.1.3. The year of 1929 and the Great Crash

The year of 1929 began with a lull on the market. Despite the fact that, according with Galbraith (1954), the volume of stocks traded in January exceeded 5.000.000 in five days, in February, the decrease in the UK reference rate slowed the rhythm of trading. The first glimpse of what was to happen in October came in March that year. On 25th March stock prices fell, and with the rate of broker loans increased to 14%; the following day a wave of fear resulted in a volume of 8.000.000 stocks traded. Prices plummeted and both investors and brokers were panicking. The interest rate on brokers' loans reached 20% and telegrams began arriving requesting the delivery of the guaranty deposits. It was only Charles Mitchell's announcement that the Federal Reserve was obliged to stop a possible crisis that brought this panic under control (Galbraith, 1954). The power of information was doing its work. Also, 1929 would be characterized by the extreme flow of information from the most diverse sources, trying to bring calm and confidence to the markets.

Brokers' loans indicate the degree of speculation on the market, and they were reaching high levels by this time. However, the interest rate indexed to these loans was more volatile than at other times. This dichotomy demonstrates the conflict of expectations. On one hand, investors believed that the market would continue to rise. On the other, brokers were more uncertain (White, 1990).

Market behavior was "normal" until August with days of trading seen as the last of the great 1920s. But despite this behavior, some macroeconomic indicators were telling a slightly different story. In July, the industrial production index reached a peak and went into decline the following months. The problem was based on the fact that the stock market only feels the effects of this context with some delay, and only when the investors and all the market becomes aware of the macroeconomic situation. But at this time, investors were still confident (Galbraith, 1954).

In September and October the market started to slow and Galbraith (1954) and Allen (1931) stated that September represented the end of the golden days. Nevertheless, investors' expectations about the future were still quite optimistic in early October.

Though high on October 15, the situation started to change on October 19. The news was that stock prices were falling and the guarantee margins were rising, which meant that prices were getting so low that they no longer represented the guarantee on the loans. On October 21 the market was unstable but losses were covered at the end of the day. Then a normal idea started to circulate: sell stocks and buy gold. Despite the announcement by bankers that the market was fine, on October 23 there were continued losses and this led to the pre-crash on October, 24 (Galbraith, 1954; Sornette, 2003).

On that day, the volume of stocks traded reached 12.900.000 and panic started to set in. Prices started to fall and most transactions were to sell stocks. The uncertainty fueling the panic was only controlled at midday when a group of bankers met to discuss what to do and how to save the stock market. They decided to gather resources. But it was what the bankers told to investors and not the resources that stabilized the market. The relieved investors started trading again so as to be part of the new wave of prices increases and by the end of the day the majority of the losses were compensated. The wave of confidence in bankers restored calm and everything was thought to be back to normal. It was now important not to miss the opportunity to buy stocks that were cheaper than ever (Galbraith, 1954; Sornette, 2003).

Despite the restored levels of confidence, October 28 started with losses and was a very difficult day on the market. The volume was high and most stocks were falling. The Dow Jones Industrial Average dropped almost 40 points and the volume was very high. The bankers met again but unlike the previous meeting, now the concern was how not to help the market without increasing the wave of panic. But it was clear the next day that this idea had not worked. The final loss that day, known as Black Tuesday, was a little lower than the previous day but combined all the bad characteristics of the previous days . The volume of trading hit a historic maximum of 16.410.000 stocks and the Dow Jones Industrial Average dropped almost 30 points. The main company stocks continued to fall and stocks of trust funds were going to zero value as the volume of brokers' loans was decreasing. The bankers were held responsible for this situation and the help they had promised before did not come that day. Panic and fear set in (Galbraith, 1954; White, 1990 and 2004). Over the next days, there was some recovery and the real goal was to restore confidence among the leading actors on the market. Despite a brief recovery in December, this did not happen. The margin calls decreased by 25% and the volume of brokers' loans also decreased. Some companies went bankrupt and trusts funds were seen as a negative factor to the recovery because their stocks were in steady decline and became unsellable by November (Allen, 1931; Galbraith, 1954; White, 1990).

3.2. Dot-com bubble of 2000

The 1990s was one of the most prosperous times in the USA economic and financial history. The good macroeconomic indicators, the bullish market, the launch of Internet and the advances in the technological and biotechnological sectors made Americans believe the future would be prosperous.

Like the 1920s, these general conditions - economy, market and the emergence and development of a new sector – generated expectations and beliefs surrounding a New Economy. However, unlike the 1920s when most investors were just discovering the possibilities of the financial markets, especially the stock market, in the 1990s much of the population was familiar with the market and saw it as an inherent to the normal functioning of the economy. More specifically, investors were more knowledgeable and were not restricted to a particular class. It was just as normal to have an asset portfolio or invest in the stock market as to buy the groceries or pay the bills. It is therefore no surprise that the majority of the investors were excited about new, potentially lucrative investments.

The investors' appetite was precisely satisfied with the emergence of two new sectors, namely internet and technological industries. They brought new scope to the market and, more importantly, new stocks. Soon, the hope for a New Economy was built around these companies and, like the utility sector in the 1920s, they fuelled the main channels of investment. Not surprisingly, this period of enthusiasm was followed by a speculative bubble.

3.2.1. The rise of web companies and the investor profile

In the early 1990s, the US macroeconomic environment was unstable. According to the FED (Federal Reserve), the US economy was in recession and inflation and unemployment rates were rising. As a result, the real *per capita* consumption in 1991 was the lowest that decade.

The recovery began in 1992, coinciding with the IPO (Initial Public Offer) of American Online, the first big internet company. This act (IPO) became commonplace in the following years, taking place in well-known companies like Yahoo, Amazon or E-Bay (Liu and Song, 2001).

However, following the American Online IPO, the internet only appeared in the news again in November 1993. But at that time, very few people were aware of this new industry and even fewer had access to it. However, the computer and the possibility of accessing internet had such a powerful effect on people's lives that it gradually acquired as much importance as television. The Worldwide web was even more attractive because the creation of each new application or site gave a sense of contributing to the country's economic growth (Shiller, 2000).

Investors' interest in the potential and opportunities of the web triggered an exponential growth in IPOs for web companies, and with time this resulted this same interest resulted in enormous P/E (price over earnings) values and stock returns. The subsequent bubble generated by the expansion of dot-com companies and later tech and bio-tech companies was essentially a consequence of investors' and the population's new and different mindset in relation to previous decades; like in the 1920s, they saw an opportunity to get rich with the minimum effort (Shiller, 2000).

Also, this desire for investment and wealth was reflected in cultural values. A successful business person became much more revered than a brilliant scientist or artist. The success cases in the financial markets allied to the bullish trend increasingly gave the impression that investing in stocks was a quick and easy way to get rich with little effort. But the market was not only driven by individual investors; the growth of pension plans and mutual funds were raising demand for stocks, particularly in tech and dot-com stocks which were growing at a frantic pace (Shiller, 2000).

Just as in the 1920s, the stock market seemed to offer general investor a world of opportunities and their excessive optimism gradually made him neglect the risks and believe the market was more predictable than it really was (Liu and Song, 2001; Shiller, 2000; White, 2004).

3.2.2. The speculative wave: Evolution of the Nasdaq, web and tech companies and investor behavior

The motives that triggered this situation must be analyzed before the Nasdaq speculative bubble can be understood. Clearly this speculative wave cannot be explained simply by the behavior of web companies. Like on the 1920s, an analysis of the companies' and investors' behaviors proves to be the most efficient approach.

The speculative wave that was seen on the Nasdaq Composite Index in the late 1990s is mostly associated with the huge surge in IPO's, the dramatic rise in web companies' stock prices as well as the interest and expectations of the investors in this sector. Let's look at an example. The Nasdaq Composite Index rose from 755 points at the beginning of 1995 to 5.000 points in March 2000, i.e. a valorization of 522%. The speculative bubble can also be isolated and seen at the end of 1998 and beginning of 1999 when the return rates of the Nasdaq frequently reached values of over 10% (Liu and Song, 2001; Sornette, 2003).

This evolution can be analyzed in two phases. Firstly until 1997, it was almost entirely explained by the rise of the sector and the expectations and beliefs generated among investors that this was the sector of the future. These expectations changed the natural course of the market, triggering an abnormal demand for web stocks and thus a dramatic rise in prices. Secondly, after 1998 in particular, the market and companies reacted and responded to this situation (Shiller, 2000).

Companies that were already part of the index at this time like Yahoo and e-Bay, were successful and improving their results, prices and market share and were therefore giving investors the right and expected signs. This was the ideal environment for more companies to join the market, though in many cases it proved too soon.

This rush to the market by web and tech companies, many of which had been operating for only a few years or months, boosted offer and gave investors the impression that the market was developing fast, driving them to buy more and more stocks, often speculatively, bringing a wave of money into the market. However, even though many of these new companies in the IPO process were not as strong as the stock price reflected, their price was rising every day. In conclusion, the illusion that was created of the sector and the market was unfounded. So why did these companies start the IPO process and why did they enter the market so soon?

The answer to both these questions lies with the investor. Firstly, internet and tech stocks were irrationally overpriced. The recent performance of these companies on the market and the future growth prospects combined with investors' beliefs made some young companies precipitate entry into the market to take advantage of these high prices. However, their stock prices reflected investors' beliefs and expectations for the sector rather than their actual performance because these companies were too young and their financial structure was unbalanced. In time the stocks of the entire sector and index became overvalued (Liu and Song, 2001; Schultz and Zaman, 2000).

A second explanation was the rush to grab market share. In an industry with enormous potential, an IPO provides capital for a company to invest in marketing and R&D even after losing money for several quarters as well as the possibility to acquire other companies and improve market share. As a result, the increase in the market share brings economies of scale, implying lower costs and more efficient development; in the mid-term, this improves the results of the company and its stock price (Liu and Song, 2001; Schultz and Zaman, 2000).

It can be concluded that the market changed mostly because of investors' positive expectations for internet and tech companies, which tried to gain from this by going to the market thus giving investors the impression of an expanding sector. It did not take long before stock prices ceased to be based on fundamentals, but on the beliefs of companies and investors; jointly, they caused stock prices to rise and this brought benefits to both parties.

However, the volume of short selling clearly demonstrates that as the Nasdaq improved, overpricing and speculation increased. For example, an average web firm in 2000 had almost 6 times as much of its public float shorted (Hand, 2000).

3.2.3. The year of 2000 and the Crash[1]

In 2000, tech and dot-com stocks were still increasing despite forecasts of a rise in the interest rate. When all other indices were decreasing, on January 4 the Nasdaq rose to a record of more than 4.000 points.

But Nasdaq's volatility and fragility of started to be seen on January 7 when Lucent Technologies, a maker of telephone equipment, warned about lower than expected profits and sales. After this announcement, investors started the typical strategy of rotating new and old economy stocks in their portfolio. This gathered pace and by April became more frenzied and was closely linked with rising levels of myopic risk aversion. However, the channeling of almost all available money (such as dividend and tax gains) to dot-com and tech stocks continued as the falls in the market were seen as normal corrections.

But this time, some analysts were underestimating investors' strength and power, and continued to believe that fundamentals were strongest than psychological moods. Nevertheless, most financial analysts were avoiding dot-com stocks.

Moreover, the volume of short selling remained high, with an average of 2.4 billion shares shorted; this indicated a strong bearish mood among the aggressive group of investors even though Nasdaq stocks rose 2 or even 3 digits.

Another curious circumstance was the increase in the return rates of Nasdaq stocks despite rises in treasury bonds yields (which went from 4,8% in 1998 to 6,3% in 2000), indicating the possible speculative effect, once the investors' expectations, based on the good past performance of stocks and in the expected high consumption on the sectors to which they give support, were skewing their predictions.

The investment fever continued in February with investors holding record credit in margin debt trade. It is interesting to note that the last time there had been such a high volume of credit in the hands of investors was precisely in September 1987 - the month before Black Monday, 1987.

In March, just before the fall, Nasdaq rose to a record of 5.000 points, up from 3.000 points just four months earlier.. However, greater returns bring a serious increase in volatility, which ultimately increases the risk and consequently the costs of margin debt.

In March 10, Nasdaq reached the 5.000 point mark for the last time. In the 3 following days, it registered point drops, setting the index at 4.500 points on the so-called "correction days".

Allied to these situations, the FED began to express concern about the over-speculation on the market, indicating that these new economy companies were too

[1] This point 2.3 was made essentially using news from the economy and markets section of the New York Times and New York Daily News, from January to April

dependent on the old economy and therefore a risk to the economy.

The anxiety and uncertainty started to spread significantly when on March, 20 the Nasdaq recorded its biggest historical percentage loss, though was later exceeded negatively on March 30. Even the most optimistic investor began to question whether such a large number of corrections in such short period of time was normal?

The events of April confirmed that this was not a period of correction or adjustment but the burst of a bubble. After all, the traditional laws of economy applied to the Nasdaq. Whereas on March 10 the Nasdaq was 24% higher than January, in April the gain was only 12%. Almost immediately the margin debt rates started to increase even more than in March and the credit lenders became more suspicious about Nasdaq's behavior and future. Also, the mutation and roll-over in the composition of individual portfolios became more common, particularly among naive investors who bought tech and dot-com stocks just because they were rising.

Even for the more skeptical investor, the worst was confirmed on April 4. The market opened with countless sell orders which rapidly led to an almost 14% fall in the Nasdaq; and the volume for historical records, all of this on a day without any significant bad news. The market only recovered when the rumor that hedge funds were buying stocks and bringing liquidity to the market began to circulate, but the panic was already installed. Fear was abated when the day closed only 2% down.

The market volatility was beginning to hit most investors who were losing capital and running out of cash to cover their losses. On the other hand, some aggressive investors saw this as a unique opportunity to buy stocks and to gain with the possible recuperation. However, even the biggest tech and dot-com companies were announcing losses and the commercial banks began to refuse money to invest in dot-com stocks, starting a run on convertible bonds.

But the decline continued and by April 12 the Nasdaq had already lost more than 25% since its peak, closing the day more than 7% down at 3.769 points - the lowest at close of day since January. Already fully aware of what was happening, on April 14 Nasdaq recorded its biggest 1 day loss ever, down more than 10% to 3.321 points. The week closed with a 7 day fall of 25%, the worst week in its history.

The Nasdaq never again reached the levels witnessed in this period and it continued to fall for a few more months. In addition, the USA subsequently went into macroeconomic recession and innumerous tech and dot-com companies went bankrupt.

4. An Iterated Prisoners Dilemma approach

This research addresses investor behavior in the stock market in extreme situations of speculation and crash. In this context, the game chosen to obtain a significant explanatory efficiency must contain more than two individuals and, in this case, a finite but indeterminate number of investors. Despite the possibility of constructing a model with players acting either individually or as different groups, it was chosen the first alternative (N players acting individually) because joining individuals in groups can be complex given the need to access an enormous amount of information in order to form groups with a higher percentage of similarities.

Moreover, a one period static model was discarded due to its lack of efficiency in situations in which behaviors and actions tend to evolve over time and in response to the actions of adversaries. Therefore, a game was created with T infinite periods of time. However, the temporal horizon of the present game will be comprehended between [0+d;T-d], $d\neq 0$, implying the analysis of a sub-game. This procedure was selected because the objective is to focus on the speculation and crash periods, which are only a fraction of the time T. Hence, there are d periods of time before the speculation period and d periods after the crash, which implies that the game has a partial but not a final result, because the game itself will continuously evolve to other states after the end of the sub-game analyzed.

The aim is also to analyze the appearance of both cooperative and non cooperative behaviors as the game matures, what excludes games that do not consider the possibly of an evolution in aggregate behaviors and subsequent equilibriums. The context of information is asymmetric and imperfect; it is perceived and used gradually by the players, which does not imply *à priori* that they have advantage over the others. Thus, allied to this, the game is sequential because the investors do not act at the exactly same period of time, opening possibilities for the application of strategies that mutate in response to other players' actions.

Finally, it is assumed that the investor is not fully rational; this implies that despite the prior objective of optimizing his results, his actions can lead him to inefficient outcomes. Accordingly, the following game will not be based on a payoff function that expresses the result of the game for the player, but on a function that will explain the incentive to cooperate and defect.

Moreover, as investor preferences are not stable and rigid, actions can vary considerably in different time periods, making preferences closer to a hyperbolic function which considers the possibility of preference reversal.

Given the abovementioned assumptions, an Iterated Prisoner's Dilemma game (IPD) was selected and applied to N players and for the given temporal horizon mentioned, with non zero sum result, which indicates that the benefits and incentives to cooperate are not necessarily the same for defecting.

In the basic form (for 2 players), the IPD assumes that each player can choose to cooperate or defect; the game can be repeated or iterated as many times as needed in a sequential fashion, implying that the strategies used can mutate according with each player's previous action. It is important to note that the players do not know the length of the game, thus invalidating an end behavior effect which may arise in super-games with finite time periods (Selten and Stoecker, 1986).

Thus, the game can be presented in the following matrix form.

Table 1: Standard Payoff Matrix (canonical form) of the IPD for 2 players

	Cooperate	Defect
Cooperate	R, R	S, T
Defect	T, S	P, P

In addition, the game will only be an IPD if the following assumptions are respected:

a) T > R > P > S;

b) $R > \frac{S+T}{2}$

It is assumed that circumstantial cooperative equilibriums may occur, but that these will not be dominant and stable (Aumann, 1959). As the number of iterations increase, a Nash Equilibrium can be reached but only if the players have monotonic preferences, which is easier to achieve with 2 players.

However, the 2 player form of the game is considered to be reductive because, when dealing with real-life situations, more realistic results can be obtained with an N player game (Davis *et al*, 1976).

It has been therefore selected the more usual approach, namely an N player IPD, which implies the following:

- Each player faces two choices: cooperation or defection;
- The defection (D) is a dominant pure strategy for each player and it will be better if he always choose that option;
- The equilibriums achieved are not stable in some cases, principally in cases of cooperation (C).

Thus, the game can be presented as follows.

Table 2: Matrix presentation of the IPD for N players

Nº of Cooperators	0	1	…	X	…	N-1
Cooperate	C_0	C_1	…	C_x	…	C_{N-1}
Defect	D_0	D_1	…	D_x	…	D_{N-1}

As in the 2 player form, with N players the game will only be an IPD if the following conditions are achieved:

a) $D_x > C_x$ for $0 \leq x \leq N-1$

b) $D_{x+1} > D_x$ and $C_{x+1} > C_x$ for $0 \leq x < N-1$

c) $C_x > (D_x + C_{x-1})/2$ for $0 < x < N-1$

In a concrete model, the C_{N-1} and D_{N-1}will be payoff functions that translate the incentive to actions of cooperation and/or defection.

One of the important features of this model is the possibility of mutation in the behavior and actions made across the game (dealing only with pure alternatives) and this can be expressed with resource to the strategies used.

Nevertheless, players in the real world do not know the actions taken by others in real time, and there is a delay that can be caused by innumerous factors. Hence, the investor only knows the adversary moves with a $\lfloor$ period delay, improving his knowledge of the game with time (memory), i.e. he will learn as the game evolves. This learning ability is a very important factor to avoid the possibility of superrational players. Moreover, even with the premise of learning and delay, some mistakes can be made by the player because he is unable to process all the available information and therefore selects information using anchors and heuristics; this can lead to judgment errors.

4.1. The application of the ITD to investor behavior in extreme financial events

After contextualizing the model to be applied (IPD), on the following pages it is defined the problem and the parameters of the model before analyzing the results obtained.

4.1.1. Problem definition

The above mentioned examples of financial crashes of 1929 and 2000 demonstrate that the investor faces two distinct situations. First, the context of a speculative bubble whereupon the investor increased or maintained his positions in overvalued stocks, especially in companies belonging to the new sector of the time (utility in the 1920s and dot-com and new technologies in the late 1990s). At that time he was being driven both by the desire to maximize profits and emotional considerations like euphoria and mania. Also, despite the short duration of the speculative bubble generated, the returns and the volatility implied in the stocks is linked more to increasing demand by investors than to other factors, thus suggesting a more deterministic trend in these periods than others in which the random walk prevails.

Secondly, there are crash situations and these have a different profile. Unlike the bubble context, the investor tries to avoid losses at all cost. However, this feature does not appear unexpectedly so the transition made between speculation and crash is not sudden. In the months before the crash in 1929 and 2000, a market scenario compounded with more volatility and rising but more unstable trend in prices was observed. It can be also assumed that some investors were starting to have doubts about the real value of the stocks in their portfolios by this time. However, initially the defection from these positions was made by a minority; most investors started to sell their positions at the moment of the crash, thus decreasing the liquidity and increasing the volatility on the market.

Given these two contexts, the problem to be applied to the IPD can be presented as follows: the investor has two choices, both on speculation and crash. He can cooperate with the rest of the investors to maintain the speculative bubble and the rising trend, or he can defect and invest in other kind of assets, which means that he is not interested in maintaining the situation of speculation. Thus, the players in the game can take the following actions:

- **Cooperation (C)**: can be seen as a collaboration between investors to maintain (even if unconsciously) the speculative bubble by investing or sustaining positions on stocks that are overvalued;
- **Defection (D)**: logically this is the opposite situation, i.e., the investor is not interested in maintaining the bubble and thus takes two possible actions: the investor does not want to invest in this kind of stock, or he has these stocks but does not want to maintain his position and therefore sells them and does not support the trend.

Defection can also result in the possibility of leaving the game or remaining but with positions in different assets.

4.1.2. The formalization of the game

(a) Players

The number of players in the game is indeterminate but is a finite set of dimension N. Also, for each player $i \in N$ is a nonempty set A_i of actions available that are pure: cooperation or defection. The players have the following characteristics:

- They are not fully rational, acting more in line with the Simon's (1955) postulate of limited rationality which implies that at some time in the game they may not optimize their actions; this may lead to the maintenance of long periods of cooperation;
- They do not have monotonic preferences or a stable set of preferences, which means that there is not a relation $\succ_i$ on A. Instead they may have hyperbolic preferences which allows for mutation in the preference set and reversal of a preference A over preference B in a given time period T_i;
- The risk profile of the players/investors respects the Prospect Theory utility function, which means that they are not always risk averse. The degree will depend on and vary according to whether they are dealing with gains or losses.
- Although a player can exit the game when he defects, however that is not a dominant attitude across all group members, i.e., when they defect, they can still be part of the game but with investments in other assets, or they can even observe and then enter again at a later time.

(b) Time

This game considers an infinite time period T. However, the game begins a few periods before the beginning of the bubble and continues when this analysis ends, evolving in more *d* time periods. This also implies that the model occurs in a sub-game; this does not represent a problem because, as argued by Friedman (1991), a game that begins in a given time period that does not coincide with the time period T_0 may have all the same characteristics as a game and realize the same *equilibria*.

(c) Payoff or incentive function

The payoff function in the IPD works as a mathematical translation of the incentive to cooperate. Thus, there are two payoff functions: one for cooperation and another for defection. However, neither of them is static and stable, varying with the number of cooperators, which also varies according to the strategies used by each player.

The payoff functions are denominated C_x and D_x and belong to a space set N of the number of cooperators between {*0,1,2,…,N-1*}

(d) Information and strategies

The game is played in an imperfect information context in which it is assumed that players have to make decisions at several moments without knowing all the game history or the adversaries' choices (Fiani, 2004). However, as the investor is not fully rational, it is implied that even decisions made in a perfect information context would not be supported by all known information because of their cognitive limitations.

In addition, players' actions are supported by the use of Tit-for-Tat strategy. However, because the game begins at $0+d$ time periods, it is impossible to know when the first move of defection really happened. Nevertheless, it is important to say that players take the choices made by adversaries into consideration, but with a $\lfloor$ lag period which is not standard for all players. This must be assumed because, without lagging, the game was on a short period stabilized on a Nash Equilibrium of defection (and therefore the preferences monotonic). Also, they will not remember all the previous moves from the lag period because of the amount of information, and it is therefore assumed that only a few moves prior to the lag period will be remembered.

4.1.3. The model and results

The initial problem investor's face is to preserve the speculative bubble, maintaining their positions or investing in assets that are overvalued, which implies taking cooperative actions. However, as time evolves, more investors will share similar investment decisions and this implies a stronger incentive to cooperate than to defect. But some investors realize the situation can be unstable as the bubble matures, and see defection as a more appealing incentive.

Given this problem, the following payoff functions can be applied, proposed by Seo, Cho and Yao (2000).

$$C_x = \frac{1}{2}x^2 - k \; for \; 0 \leq x \leq N \quad (3)$$

$$D_x = \sqrt{2x} \;\; for \; 0 \leq x \leq N \quad (4)$$

Note that x expresses the number of cooperators in the game in each time period T_i and k is an unknown variable that indicates the exogenous incentive to defection, which can include any type of information (even a crucial piece that can trigger the crash), being seized only by some players. However, they will start to defect when this parameter k becomes too big, making the incentive to cooperate smaller than the respective one to defect.

Also, as referred, the players make use of a Tit-for-Tat strategy, which implies that the decisions made will take the actions taken by other players into consideration, but only a small number of moves and with temporal lag.

$$l = \; y, for \; all \; T_i \quad (5)$$

$$m = (\omega * T) - l, for \; all \; T_i \quad (6)$$

Therefore, based on the idea of Axelrod (1987), the equation (5) indicates the number of lag periods in all the time T_i period, and equation (6) provides a quantification of how many periods of information a player can remember prior to the lag, where ω (a constant) is the percentage of the fullness of periods prior to the lag .

However, the players will only remember the moves made by some adversaries, mainly because it is a context of incomplete information and the investor cannot assimilate an unreal amount of information.

Thus, despite the natural dominance of defection, as shown in Figure 3, with a small k, as the number of cooperators grows, the incentive to cooperate will increase more quickly than to defect, thus implying an intersection between both incentives at a given point in time in which cooperation thereafter becomes more appealing.

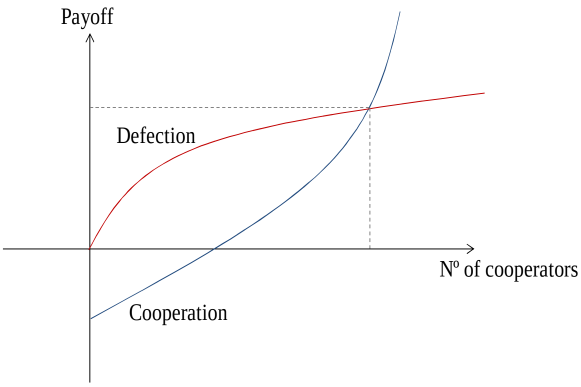

Figure 3: The evolution of the payoff result for Cooperation and Defection across a growing number of cooperators

Therefore, the game can be analyzed in two distinct parts.

The first begins on the initial intersection point described in Figure 4 as point (1). The k value at this time is small and investors are making use of a Tit-for-Tat strategy. As mentioned, the moment at which the game starts is not relevant to the present study. Thus, the period starting at point (1) is linked to sentiments of euphoria and mania, as seen in the 1929 and 2000 bubbles, when an increasing number of investors were investing in overvalued positions.

The number of cooperators starts rising rapidly and this may be due to the desire to make gains with stocks belonging mostly to sectors of the new economy, as seen with the utility sector in 1929 and dot-com and technologies in 2000. Thus, as the existing cooperators maintain their positions, partially due to the strategy being used, new players begin cooperating so as to enjoy the evident returns. The rising trend in cooperating players causes the speculative bubble to grow, as does the incentive that sustains it.

This scenario can be characterized as a minimal equilibrium of cooperation because the number of cooperators is bigger than that of defectors, and the growth of the incentive to cooperate is more accentuated than the one linked to defection. Hence, with the maintenance of a low k, the number of cooperators continues to rise to a point at which the equilibrium reaches its strongest position (point (2) on Figure 4). Thus, the peak of the speculative bubble (or minimal equilibrium of cooperation) in point (2) coincides with moments seen in the two events previously analyzed. In the Great Crash of 1929, it refers to late 1928 when the volume of stocks traded exceeded utopian marks for that time of 5 and 6 million stocks. In the crash of 2000, this is the moment when Nasdaq reached 5.000 points.

Thereafter, the equilibrium becomes more unstable. In the events described, the markets became more unstable and volatile after the peak, and investors, banks and states became more anxious and nervous. The irregularity of the market can be seen as a result of a rising number of investors starting to defect. The explanation for this defection may reside in the value of parameter k. This parameter contains pieces of information that indicate that the bubble is not stable and that it is better to start leaving the positions held on overvalued assets before a stressful drop in the market. However, this information is only perceived by some investors. Thus, some cease to cooperate and the equilibrium becomes more volatile.

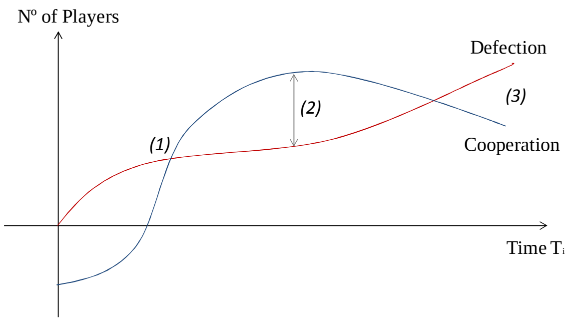

Figure 4: The evolution of the number of players cooperating or defecting across time: (1) indicates the beginning of the minimal equilibrium of cooperation; (2) Point in time at which the minimal equilibrium of cooperation is strongest; (3) Beginning of the minimal equilibrium of defection which will become stronger but not stable as a solution of the game

This moment marks the beginning of the end of that period. As more players become aware of the key pieces of information, they start to see the cooperative payoff diminishing at a faster pace than that of defection; this is explained by the value of k, which is reducing the incentive. There is a causality relation in which more k implies less cooperation and therefore a downward trend in the cooperative incentive.

As the players are using a Tit-For-Tat strategy, they start to realize some defective actions in some other players and therefore also start also to replicate their actions and choose defection; this implies a reversal of preferences that had been relatively stable for a long period of time (period coincident with speculation). This implies another intersection between the number of players cooperating and defecting. This intersection will leads to moment (3) and can be associated to the beginning of the crash.

As referred, the moment after the peak of the bubble is related to an environment of increasing volatility and anxiety among market agents. The more unstable variations of the market can be interpreted as more defective actions made by players. Hence, the game reaches a new equilibrium when more players are defecting than cooperating; this is a minimal defection equilibrium which coincides with the moments related with the crash on the market. As more players defect, the incentives decline but the incentive to cooperate becomes smaller more quickly than to defect. Thus, the gain of stability in the equilibrium coincides with the fall of the market, implying also domination over the previous one.

Nevertheless, this equilibrium will not be stable for a long period of time because investors do not have a rigid set of preferences, implying the inexistence of a Nash point of equilibrium. However, in future time periods the dominating equilibrium will evolve to other types of state.

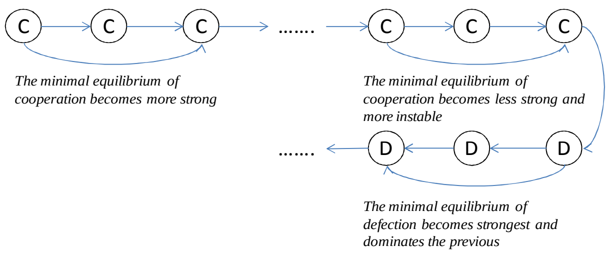

Figure 5: An illustrative diagram of transition between the equilibriums of the game

As established in Figure 5, the problem has three phases. The first involves the growth of the minimal equilibrium of cooperation, coinciding with the expansion of the speculation period. The second period is characterized by increasing instability on the markets, associated to more defective actions made by investors and making the equilibrium volatile. The final period marks the transition between equilibriums and coincides with the crash on the markets and implies the choice to defect dominates for most players.

5. Concluding notes

This research aimed to address the behavior of investors in extreme situations on the stock market. The main purpose was to shed light on some features of the investor profile in these situations so as to understand actions taken individually and as a group.

Thus, to obtain a realistic investor profile in those situations, the main features of the investor were approached in a number of ways. First, the postulate of rationality was analyzed and the existing literature on asset pricing and portfolio theory was set against the ideas of behaviorists and neuroscientists; they confirm first that the economic agent is not fully rational, being maybe closer to Simon's (1955) notion of limited rationality and second, that feasible models and theories can be constructed which do not take pure rationality as the central premise the. In addition to behavioral economics and finance, the evolutionism approach and neuroeconomics also seem to agree that the utilitarian agent is not the most efficient way to address some problems.

The decision-making process is another key feature, particularly with regard the investor's set of preferences. If the options offered in the real world are systematically changing and the actual individual has a dynamic and mutated set of preferences which may be biased by the influence of limited rationality and information processing, then the process of decision making has to be more complex than shown and derived by some theories. Considerations about the utility function and the set of preferences, the degree of risk aversion or the process of accounting gains and losses by the economic agent become so complex that it is difficult to resume all in simple axioms. However, it was showed that the complexity of the agent's profile implies that new models, and the one analyzed in this study, have to take this kind of consideration into account.

Given the above, the model generated through the Iterated Prisoner's Dilemma gives rise to the hypothesis of the existence of minimal equilibriums of cooperation (in the speculative bubble event) and defection (at previous moments and during the crash period), which are not stable because of players' perceptions of key information and their impact on the set of preferences. However, it was found that there equilibriums play a successive role if the aim is to see the game as a whole and not as a sub-game. It should also be stressed that when individuals act as a group, they do not secure cooperation, and self-interest is a key factor in the decisions made. Nevertheless, investors' motivations in the speculative bubble event can degenerate on attitudes of cooperation, as commonly seen at times on commons tragedies in natural resources. In conclusion, the proposed hypothesis launched was corroborated by the model used. However, the results can vary in line with the type of event analyzed.

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