

Neuroeconomics: Decisions in Extreme Situations

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Abstract

The role of the electorate has been confirmed as fundamental to the development of democratic countries. However, governments and large corporations have increasingly intervened in the decision-making capacity of the voters who are now seen as “customers”. This is the starting point for this article that will discuss the power of external influence in the decision-making process of the act the polling day and the importance of the context effect in the decision-making process of individuals.

Keywords: Elections, Neuroeconomics, Context effect, decision-making, Brazil

Introduction

For a long time, philosophers and scholars of human behavior believed (and generally considered) that the individual was able to take his decisions in a rational way and thus it was possible to optimize his performance considering the different decision moments along the day. May be the phrase that best represents this is that of the Chilean poet, Pablo Neruda: “*you are free to make your own choices but you are a prisoner of the resulting consequences*”.

With the emergence of the Neurosciences and their effective research techniques of the brain, the study of human behavior has evidenced a considerable bias about human rationality hypothesis, in particular, in times of economic decision.

It is possible to identify notable scholars of human behavior and neurosciences making references to a set of relating areas in the development of this subject. It is important to consider authors who, among others, are already references nowadays, such as Daniel Kahneman (1934), Antonio Damasio (1944), Patrick Renvoise (2009), Geoffrey Miller (1965), Nassim Taleb (1960).

The decision-making problems concerning the “electoral process” have been shown as a kind of infinite possibilities for new studies about the decision-making process from a neuroeconomics point of view [1,2]. This article represents another small contribution in this field of study.

Moreover this topic is of great importance for the society as a whole. Considering particularly the new global socioeconomic configuration, there exists a considerable inter-relationship and influences between the political and the economic spheres. It is interesting to report that *The Economist* Journal ranked only 30 out of a total of 167 countries as “full democracies”, 50 as “flawed democracies” and 87 as “hybrid democracies” [3].

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The real power is definitely not on the side of whoever is choosing. The decision occurs in a fraction of 2.5 thousandths of a second and several brain mechanisms are involved in the process of creating the preference after occurring the choice. This generates a series of biases as it is the case of the decision-making process concerning time [4], anchoring [5,6] equity and corruption [7], law of small numbers [8], among other deleterious effects of reason.

From a certain point of view the electorate should consider a rational approach given the choices at the polls. However, as will be seen in this article, considering the case of Brazil, it does not.

Some Conceptual Considerations

Neuroeconomics is the fusion not only of Neuroscience with Economics as the name directly suggests, but happens also as the junction of many other disciplines (biology, physics, chemistry, statistics, mathematics, psychology, pharmacology, among others) that go in the direction of a decision-making process more 'realistic' and suitable for the everyday life on the part of economic agents. Neuroeconomics arose from the need of achieving the most reliable results on the individual's economic decisions.

Although putting the concepts of Neuroeconomics as the "theoretical framework" it is not possible to assert that there are Neuroeconomic theories as it occurs in traditional Economics. Neuroeconomics is the outcome of a set of biological and mathematical results of situations of cerebral processes of people's decision making in Economics. Neuroeconomics is a new field of study in the Economics field that analyzes the relationship between the internal organization of the brain and individuals behavior. It is based on individual decision-making, social interaction and on institutions such as the market [9]. It is also an emerging transdisciplinary field which uses neuroscience measurement techniques to identify the neural substrates associated with economic decisions [10].

However, there are some cases, in which the combination of concepts and practices of Neuroeconomics with traditional methodologies occurs, as it happens, for example, with the use of applied mathematical axioms [11].

This new field of study has at its core the premise that human beings are under bounded rationality and are driven by cognitive biases unconsciously derived; and for this Neuroeconomics proposes a particular vision vis-à-vis the traditional vision of traditional Economics. This new vision guarantees a significant importance in the development of economic studies which represent a reliable way for the decision making and for understanding the current complex economic problems in this new era of complex decision making processes.

The Study

To introduce bias in decision making, two studies will be presented related to the decision-making process in "real life". The first one deals with decision-making in electoral processes [12]. The second study refers to the decision-making in situations of context, particularly in the Brazilian electric sector [13]. In both cases there are relationships between the difficulty that people have in the decision-making process and in optimizing the psychological and brain process of decision-making mechanisms.

Neuroeconomics and elections

Recently the appreciation of emotions in decision making has been in growing analysis. One of these studies was published in 2013 with the title of "the neuroeconomics of emotional conflicts in moral dilemma judgment". The study developed by professors at the University of Sao Paulo (USP), presented results concerning the referendum on the legalization of the use of firearms in Brazil. This study allows the visualization of the existence of a certain inconsistency between optimization and actual results which are found in life.

Some considerations are needed on optimization. For orthodox economists, people are represented by the homo economicus. The homo economicus is an archetype created by orthodox economists to serve as a basis for economic analysis on decision-making moments. Therefore, whenever placed in a situation of economic decision the economic agent would optimize their results. However, the idea that guides the possibility of humans as economic results optimizers was placed into question in recent studies [5,7,14].

Biological organisms immediately charge the gains by means of a reward system or brain punishment. Indeed, Neuroeconomics provides tools that allow studying the interrelationship between cognition and emotion in the solution of the decision-making conflict. In this context, it may be proposed that the utility, $u(d)$, of a decision-making, d , is a function of the conflict, $c(P_1, P_2)$, that result from arguments, P_1, P_2 , that support that decision, d . It can also be assumed that $c(P_1, P_2)$ depends on the expected utility $e(P_i)$ of each argument $P_i (i=1,2)$.

Following that approach, Rocha *et al.* [12] use Neuroeconomics tools (based on emotional aspects, especially in reward and punishment reactions) to study and model the neurodynamics of decision-making in the real context of the Brazilian elections. A presentation of the proposed model follows.

According to McClure *et al.* [15] cited by Rocha *et al.* [12], it is possible to model the discrepancy between short-term and long-term preferences, proposing that the present discounted value of a received reward with delay t is given by u for $t=0$, and by $\beta\delta^t u$ for $t>0$, where $0<\beta\leq 1$ and $0<\delta\leq 1$.

If the activity β can be best described by a particular phenomenon or as part of a discounted smooth curve that cannot be detected by fMRI methods, or both, there exist a problem of mathematical nature difficult to solve [16]. Thus, McClure *et al.* [15] propose a compromise solution, in which β is modeled by a monotone increasing function of time, which describes the enhancement of $e(a)$, of the satisfaction of n to generate m , being delayed, $e(P_i)$ being calculated as

$$e(P_i) = \beta_i^{1/k_i t} \delta_i^{n_i t} \quad (1)$$

In which $\beta_i^{k_i t}$ models the benefit of P_i and $\delta^{n_i t}$ formalizes this benefit in discounted terms.

The risk assessment proposed by biologists [17] or by economists and psychologists [18,19], led Rocha *et al.* [12] to propose the risk $e(P_i)$ of P_i being defined as:

$$r(P_i) = \frac{\rho^{k_i t} \delta^{n_i t}}{\rho^{k_i t} (1 - \rho)^{k_i t}} \quad (2)$$

where $\rho^{k_i t}$ modes risk in t of P_i and $\delta^{n_i t}$ formalizes the discount in risk.

The conflict in decision making can result from two sources:

- a. When $e(P_1), r(P_1) \rightarrow 1$ during the decision about P_1 either in IES or in PES, such as the case of voting decisions in a referendum;
- b. When $e(P_1), e(P_2) \rightarrow 1$ when P_1 is assumed to be an utilitarian social action evaluated in IES and is a personal action evaluated in PES. In this case, the conflict ($c(P_1) = e(P_2)$) is assumed to depend upon $e(P_1), e(P_2)$, being maximum if $e(P_1) = e(P_2)$, and it should be measured in the closed interval (0,1).

If so,

$$c(P_1, P_2) = -(e(P_1) + e(P_2)) \left(e_n(P_1) \log_2 e_n(P_1) + e_n(P_2) \log_2 e_n(P_2) \right), \quad (3)$$

$$e_n(P_1) = \frac{e(P_1)}{(e(P_1) + e(P_2))}; e_n(P_2) = \frac{e(P_2)}{(e(P_1) + e(P_2))}$$

A poll involves as many decisions as candidates or alternatives. In the case of a referendum, the vote often requires a decision over supporting, $e(Y)$ or $e(N)$, or rejecting, $r(Y)$ or $r(N)$ each of the alternatives: to vote "Yes" or "No". Accordingly, the conflict $c(Y), c(N)$ on voting "Yes" or "No" is calculated as

$$c(Y) = -(e(Y) + r(Y)) \left[e(Y) \log_2 e(Y) + r(Y) \log_2 r(Y) \right] \quad (4)$$

$$c(N) = -(e(N) + r(N)) \left[e(N) \log_2 e(N) + r(N) \log_2 r(N) \right]$$

The conflict increases the difficulty of decision-making which reaches its maximum at 0.5, precisely when $c(P_1|P_2) = 1 (c(Y)=1; c(N)=1)$. Therefore, the utility $u(P_1|P_2)$ of deciding P_1 given P_2 is given as follows:

$$u(P_1|P_2) = (1 - c(P_1, P_2) / 2) \quad (5)$$

Assuming its minimum value 0.5 when $c(P_1, P_2) = 1$. Similarly

$$u(Y) = (1 - c(Y) / 2), u(N) = (1 - c(N) / 2) \quad (6)$$

It is assumed that $u(P_i) > 0$ if $c(P_i) \rightarrow 1$ given that a decision must always be taken in order to avoid compromising the operationality efficiency of actions in daily life.

The resolution of the dilemma in the Greene grid of hypotheses is conditioned by the time the volunteer decides to spend in the implementation of the experiment, even being allowed to use all the time that he needs to decide on the suitability of P_1 given P_2 . It is assumed that the total conflict limits the decision-making to a finite time, in order to avoid that difficult problems ($u(D) = 0.5$) restrict the individual to specific decisions, compromising their viability in terms of his actions operationality efficiency [20,21].

The allocation of the maximum time T_r for decision-making is proposed by the formula:

$$T_r(t) = T_r(t-1) - \alpha_1 c \quad (7)$$

Such that the decision-making should occur while $T_r > 0$. Furthermore, the accumulated conflict $a(t)$ is calculated as

$$a(t) = \alpha_2 a(t-1) + c \quad (8)$$

The probability $p_t(P_1|P_2)$ to decide at time t over P_1 given P_2 is obtained as follows:

$$\begin{aligned} \text{if } T_r(t) > 0 \text{ then } p_t(P_1|P_2) &= N(e(D) * a(t)) \\ \text{otherwise } p_t(P_1|P_2) &= \alpha_3 p_{t-1}(P_1|P_2) \end{aligned} \quad (9)$$

Where α_i are different constants and N is a normalizing function that keeps $p_t(P_1|P_2)$ in the range (0,1).

The decision to vote is less constrained by time because voters can make their decisions at any time before the Election Day. On this basis, it is proposed that

$$v(Y \text{ or } N) = N(e(Yes \text{ or } No) \times u(Yes \text{ or } No)) \quad (10)$$

In order to clarify the concepts and the applicability of this model, an experiment on a referendum held in Brazil is presented below.

In order to clarify the concepts and the applicability of this model, an experiment on a referendum held in Brazil is presented below.

In the mid-2000s in Brazil a national referendum occurred on the prohibition of the marketing of firearms in the country. In Brazil the vote is mandatory and free election campaign has greater impact on TV and on the radio because it covers the whole Brazilian territory. The electoral campaign process was held for 40 days.

During the campaign, two political alliances in the Brazilian Congress have emerged, one favorable to the YES (prohibition of the trade in firearms) and another to the NO (against the prohibition of the trade in firearms).

In the study carried out by Rocha *et al.* [12] a description of the experiment in question is made. A week before the referendum 1136 people were interviewed for this study, in order to know from the respondents which is their intention to vote (represented by v) and whether they could change their mind until the election day. In this case it is possible to have a second opinion of vote (represented by v').

Next week, you have to vote in the referendum on the prohibition of the trade in firearms in your country. Select one or more of the following options to best describe your opinion on the prohibition of the sale of firearms in Brazil.	
I will certainly vote YES (CY)	I will certainly vote YES (CY)
I will probably vote YES (PY)	I will probably vote YES (PY)
Certainly I will not vote YES (NY)	Certainly I will not vote YES (NY)
I have not yet decided my vote (ND)	I have not yet decided my vote (ND)
Certainly I will not vote NO (NN)	Certainly I will not vote NO (NN)
I will probably vote NO (PN)	I will probably vote NO (PN)
I will certainly vote NO (CN)	I will certainly vote NO (CN)
First opinion: Vote v .	Second opinion: Vote v' .

Table 1: Vote Options.

Table 1 shows the observed percentages for each type of response. Considering the votes “possible” and “sure”, the study shows there is a balance between the YES votes and NO, which is due to the similarity of values between the probability $p(Y)$ to vote YES and $p(N)$ to vote NO, calculated from those that responded v . That is:

$$\begin{aligned}
 p(Y) &= p(CY) + p(PY) = 25\% + 7\% = 32\%, \\
 p(N) &= p(CN) + p(PN) = 26\% + 8\% = 34\%
 \end{aligned}
 \tag{11}$$

However 14% of the volunteers provided a second opinion showing that they could change their mind on the Election Day (voting v' in Table 1). Taking into account a possible migration of votes, the final voting percentages are $p''(Y)$ and $p''(N)$, being calculated column v'' in Table 1, as

$$p''(Y) = p(CY) + p(PY) = 31\% \text{ and } p''(N) = p(CN) + p(PN) = 44\%
 \tag{12}$$

pointing to the same victory of the NO vote on the election day.

	Vote		
	v	v'	v''
$p(CY)$	0,25	0,03	0,26
$p(PY)$	0,07	0,01	0,05
$p(NY)$	0,10	0,00	0,06
$p(ND)$	0,19	0,00	0,17
$p(NN)$	0,04	0,01	0,007
$p(PN)$	0,06	0,04	0,10
$p(CN)$	0,28	0,05	0,35
	1,00	0,14	1,00

Table 2: Inquiry Data [12].

Let us consider the possible and “sure” votes provide a measure of acceptance of the vote $e(Y \text{ or } N)$ in such a way that:

$$e(Y) = (p(Y) / (p(Y) + p(PN))) \text{ e } e(vN) = (p(N) / (p(Y) + p(PN)))
 \tag{13}$$

The analysis of possible vote migration showed that those who voted “Certainly I will not vote YES (NY)” migrated to the NO vote while those who voted “Certainly I will not vote NO (NN)” migrated to the YES vote. In addition, some volunteers who voted for “I have not yet decided my vote (ND)” migrated to the NO vote. The probability $p(NY)$ decreased from 10% to 6%, $p(NN)$ changed from 4% to 0.7%, and $p(ND)$ dropped from 19% to 17%. In this context, it is proposed that the rejection $r(Y \text{ or } N)$ is dependent upon $p(NY)$, $p(NN)$ and $p(ND)$ such that:

$$\begin{aligned} r(Y) &= (p(NY) / (p(NY) + p(NN) + p(ND))) \text{ and} \\ r(N) &= (p(NN) / (p(NY) + p(PNN) + p(ND))) \end{aligned} \quad (14)$$

The acceptance $e(N)$ to vote NO was very similar to that found in $e(Y)$ to vote YES when v is considered, but after migration, $e(N)$ becomes greater than $e(Y)$. The rejection $r(Y)$ to vote YES was higher than that of $r(N)$ to vote NO, even after the migration of votes. Note that while $r(N)$ showed a considerable reduction $r(Y)$ remained almost the same.

Before the beginning of the election campaign in August 2006, 76% of Brazilians have already showed interest in the referendum and 80% declared the intention of a YES vote Datafolha cited by Rocha *et al.* [12]. Although the campaign has not attracted much attention, people began to discuss the referendum with parents (37%) and friends (27%) IBOPE cited by Rocha *et al.* [12]. With the approach of election day, many voters changed their minds and the almost certain YES victory slipped to a YES defeat. The final result of the referendum was NO = 67% and YES = 33%. The high rejection of the YES, as calculated above, from the research data, may explain the high migration of votes as the election day approached.

The data on acceptance and rejection were used to calculate $c(Y)$ and $c(N)$, using equation 4. And the equations 6 and 10 to calculate the voting decision probabilities of Yes and No, $v_m(Y)$ and $v_m(N)$ for the two situations: the stated intention, v , and the migrated votation v' .

The forecast of the voting decision was calculated from the acceptance of voting (equation 10) and from equations 10, 12 and equation 8. The results are very similar to those observed in the referendum.

The context effect

To ascertain whether or not the “context” is important in decision making, a test was performed with 72 students of MBA in Business Management at Getulio Vargas- FGV in Belém, PA [22,23]. The test was adapted from the studies of Tversky and Kahneman [18]. The researchers presented the dilemma of the disease, in which respondents had to choose between some types of treatments in a positive perspective and others in a negative outlook. A experimental research was used (experiments type before/after-2 groups), which showed the control group and the experimental group before stimulation, then the stimulation applied in the experimental group, checking the difference between the experimental group (stimulated) and control (without stimulation). The difference between the two was the measure of the applied stimulus [13].

- 1) First the students should consider a decision about a flooded area comprising 600 families, under the following optics:
 - a. Alternative A - 200 families would be preserved on site;
 - b. Alternative B - a probability of 1/3 that the 600 families would be held in the place and 2/3 that no family would remain there;
- 2) In a second step, students should respond in a negative perspective, considering:
 - a. Alternative C - 400 families would lose their homes, and
 - b. Alternative D - a probability of 2/3 that the 600 families would lose their homes and 1/3 that no family would lose their home.

Considering the “positive results”, 57% of the students of MBA FGV responded that Option B would be the best choice, while 43% claimed that option A would be better. Considering the results for the negative context, 68% of students responded that Option D (which is exactly the same as Option B) would be the best choice to be made while 32% said that Option C would be the best among the possible.

Just as in the case of elections - on allowing or not the legalization of firearms in Brazil - the “dilemma of hydropower” proved to be highly influential on to the creation of a cognitive bias allowing modifying the choice on the timeline. This presents a usual form of rational decision-making inconsistency in extreme environments. This permits to say that when people is asked to decide about a situation of, for example, the flooding of areas in the Amazon rainforest or on the use of firearms by the Brazilian population, these situations

should be remarkable different from other ones quite different as it is the case of deciding on to choose between which smart phone to buy or which cereal bar to choose at the supermarket checkout. However, the results point to the opposite way, what means that people decide identically in whatever is the context. The degree of uncertainty, in both situations, raises the level of difficulty for the decision. Therefore, it seems that the magnitude of the decision is not important in the decision moment; what is relevant is the way, the form by which the decision it presented.

At this point a question seems to be necessary. Why this effect occurs? The answer is not easy to be answered and requires an analysis involving the brain mechanisms of decision-making. Variables such as levels of harmonium cortisol or the neurotransmitter dopamine level, for example, can serve as parameters, but also is the identification of the situation with the help of a Functional MRI machine. In fact, it is important to note not just the importance of the individual behavior, but also unconscious signals concerning impulses and feelings of emotion for each case of decision.

Conclusion

The limited capacity of decision-making by individuals strongly suggests that the individual must base his analysis on models closer to reality of the decision maker. To this end, neuroeconomic models are a real possibility.

It is possible to more accurately predict the movement of the players. Decision makers whether participants in an election or in a football game are subject to cognitive bias, hence trying to accept these biases improves the analytical capacity of the model.

The subject of decision-making is very important in it and gets dramatic contours to plead the future of society and the economy as in the referendum on the guns in Brazil.

However, it is necessary to use more advanced research techniques to the study of the brain of the decision makers. Only in this way will be possible to verify how the endogenous mechanisms of brain function at the same time that agents make their choices. Certainly the qualitative gains in the analysis results may be very considerable.

In addition to the use of more precise research forms, it is also important to submit this topic to a greater number of researches so that the greatest number of hypotheses to be tested in situations of decision-making, particularly, in the area of economic decisions.

However, it is necessary to be prudent about the generalization of the results considering the scientific and practical uses of these results. Neuroeconomics is still considered a new field of knowledge. The contribution of neuroscience and Economics considered together emerges as the formation of this new field. However, the results point to the fact that neuroeconomics appears itself as a completely new field because its premises, tests, applications and discussions have advanced to a single direction and distinct from paths that neuroscience followed and completely different from the path traced by the Orthodox economic science, if not often antagonistic.

Plainly the results found in many studies of neuro and behavioural economics show that humans are not fully rational in their decisions, for instance during elections on when deciding about other situations of complete uncertainty. This fact also emerges from data results obtained and worked on this analysis.

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