Rivista Internazionale di Scienze Sociali, 2012, n. 3, 269-288

THE SUPERFLUOUS POSTULATE OF HUMAN RATIONALITY

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ABSTRACT

If human beings were empirically shown to be irrational, would this finding destroy the foundations of economic science? We think not because we doubt that this postulate is needed as a foundation of economic science. We examine the laboratory experiments conducted by behavioral economists and experimental psychologists on human judgment and decision-making, using Bayes' Theorem and the Expected Value model. We examine a number of issues: Can we base ourselves on experimenters' full rationality for doubting of human rationality? Are rational models anything else than handy tools? Do humans' minds function like rational tools or with rational tools? How an ''irrational'' human being could create anything ''rational''? Should rationality be subordinated to reason? Nature being neither rational nor irrational, is there any point in applying the concept of rationality to one its constituents? If human beings were rational forms of life, would this specie have survived?

Keywords: Rationalty, Economic science, Decision-making, Human judgment.
JEL Classification: A12, C90, D03.

The postulate that human beings operate rational choices is the main foundation of the theoretical paradigm that dominates current economic science (e.g., Mas-Colell, Whinston and Green, 1995). Rationality is postulated in most economic models of individuals' behaviors (e.g., Becker, 1976). It is part of practically every economics manual dealing with human decision-making (e.g., Blume and Easly, 2008). Rational human decision-makers are expected to analyze the costs and benefits of every possible action and select the action that maximizes their personal gains (Friedman, 1953).

Does this mean that if human beings were empirically shown to be irrational, this would largely destroy the foundations of economic science? I think not because I personally doubt that this postulate is needed at all as a foundation of economic science. This is this skeptical attitude that I am going to explain and discuss in this article that Dr. Simona Beretta and Dr. Mario Maggioni requested me to write for this special issue.

Acknowledgment. I feel greatly indebted to Simona Beretta, Bernard Cadet, Vincent Dru, Marco Heiman, Wilson Lopez Lopez, Mario Maggioni, and Paul C. Sorum who criticized an early version of this article and offered many insightful suggestions.

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''A bird in the hand is worth two in the bush'' (English proverb)

The question of knowing whether human beings are rational or not rational is certainly not a new question. This question has, for a long time, been of much concern to philosophers (e.g., Kant, 1996). Since the middle of the seventies, however, this question was tackled empirically, and in a very systematic way, by experimental psychologists, working in the field of judgment and decision-making, and inspired by the work undertaken in the fifties by Maurice Allais (1953).

These psychologists created experimental situations in which young people in good mental health – students generally – had to choose between two options or had to assess the values taken by certain parameters in usually complex, probabilistic situations. These experimental situations were created in relation to mathematical models, mainly the Expected Value Model or Bayes' Theorem, but other models were also used as a basis for these experiments. The principle of these experiments was simple, and can be summarized in the following way: (a) chose a mathematical model, (b) create a story that contains the information that forms the ''inputs'' of this model, (c) instruct people to read the story and intuitively assess the output, (d) compute the correct output using the model, and (e) compare the two outputs, the participants' intuitive one and the one that issued from the computation (Kahneman, Slovic and Tversky, 1982).

As a concrete example, in this kind of experiment participants can be requested to choose between (a) a lottery ticket making it possible to gain 50 euros with a probability of .30 or (b) a ticket with a fixed value of 10 euros. Since the experimenter is familiar with the expected value model because it is this very model that was used as a basis for the experiment, and since the experimenter has a pocket calculator at her disposal, it is easy for her to calculate the expected value of the lottery ticket (50 euros times .30 = 15 euros), and to designate, in this situation, the first option (the choice of the lottery ticket) as the correct choice, i.e. the rational choice. Given, on the other hand, that many participants find themselves confronted for the first time of their life with a situation of this kind and do not know the expected value model, and that they do not have calculators at their disposal, it is much less easy to them to realize the stakes at hand in such situations. As a result, most of them are tempted to choose the second option; that is, to take the money without waiting more and to quietly return to their premises.

From the experimenter's point of view, choosing the second option instead of the first one can be legitimately considered as the expression of an irrational decision. If, moreover, similar behaviors can be observed in multiple circumstances, and from varied participants, then there are incontestably serious reasons to question human rationality, at least in this kind of situation. Some scientists, economists or psychologists, have, however, been charitable enough to attempt to salvage the idea of human rationality. They have, in particular, invoked the concept of risk aversion (e.g., Arrow, 1965, see also, Kahneman and Tversky, 1979). Choosing the first option exposes one to the risk of losing everything. Choosing the second option exposes one to no risk. Not exposing oneself to risk when, for example, one has a family to look after can, at first glance, be seen as a rational decision.

It follows from Arrow's suggestion that if a person chooses Option b, the reason likely to explain this choice is not the person's irrationality but the person's personality. This person can be diagnosed as presenting a personality trait called risk aversion. The problem with this diagnosis, however, is that it is just a ''mathematical'' diagnosis. It has been made on mathematical grounds. This diagnosis could have been the opposite one if the stakes at hand had been different (e.g., 150 euros instead of 50 euros). Also, this diagnosis is not a psychological diagnosis; that is, a diagnosis that would follow from the administration of validated psychological scales and that would be confirmed by a trained clinician. Maybe the ''risk-averse'' person just needed an additional 10 euros in order to buy a new bungee jumping cord. To get the 10 euros, this person was willing to run the risk of being misjudged by the experimenter as ''timorous'' in order to practice his favorite sensation-providing hobby.

Another problem with this kind of attempt at salvaging the idea of rationality by invoking participants' personal dispositions is that it is always possible to create yet another diagnostic category to rationalize the ''irrational'' choice. If not risk-aversion, it can be risk-proneness (Kahneman and Tversky, 1979) or momentary mental states (Weiss, Weiss and Edwards, 2010). Another strategy is to assert that the person was not considering money in itself by its utility; that is, what the person feels about it (Mosteller and Nogee, 1951). In this situation, the difference between the two options was, from the person's perspective, negligible.

In summary, if the researcher' s objective is to show that human beings are not rational, sticking to the expected value model is the position the researcher must adopt. By contrast, if the objective is to show that human beings are rational (after all), weakening the model until it fits the participant's choice is the way. Such a position would lead the apologist down a slippery slope so that any decision, no matter how seemingly irrational, can be made to seem rational from the individual decision maker's point of view.

My suggestion is that it would be simpler to consider that, in the laboratory situation described above, (a) choosing the lottery ticket can be considered as a reasonable decision because it makes it possible to gain 50 euros; (b) choosing the 10 euros can be considered as another reasonable decision because it ensures coming back home with some money; (c) mentally computing the expected value of the first option, realizing that it is higher than 10 euros, and nevertheless choosing the second option because of the proverb used as the title of this section can also be considered as a reasonable decision, and, finally, (d) refusing this kind of offer can also be admitted as a reasonable decision because, as is well-known in puritan circles, games played for money are immoral ones. In other words, without exploring participants' underlying true motives, as expressed by them, it may be difficult to understand much of their behavior. Just observing behaviors without asking people why they behave the way they do is potentially risky (Apter, 2001).

But now, what could constitute an unreasonable behavior in the situation described above? In fact, many behaviors: Trying to corrupt the experimenter by proposing to share the 50 euros equally without playing the game, punching the experi-

menter without any motive, painting the walls, and trying to steal laboratory equipment are instances of unreasonable behavior in the context of a psychology lab experiment.

Is it not enough to expect people to perform reasonable behaviors in their daily life without examining whether these behaviors obey an adjusted or an unadjusted mathematical model? Is economic science in danger of losing its foundations if people behave in a way that is simply reasonable although not rational? As is well known, reasonable (in Italian, ragionevole) and rational (in Italian, razionale) are issued from the same Latin root *ratio* (proportion, reason). However, the current meaning of these two words is clearly distinct, although one may wonder whether authors working in the field of economic psychology have always clearly distinguished between them.

''Testimony gives something to be interpreted'' (Paul Ricoeur)

Another kind of situation that has been much used by experimental psychologists working in the field of judgment and decision-making for examining human rationality is one in which participants are asked to assess the current probability of an event (posterior probability) when they know the general probability of this event (prior probability) and are given additional information related to the event. For example, participants may be requested to assess the probability that Vicenzo Lupini, a notorious robber, is the person who has introduced himself into the school and taken the computers. They are told that there are only two robbers in the city, a certain Arsenio Peruggia who is responsible for 80% of the offences made downtown, and this Mr. Lupini who is responsible for the complementary offences (20%). They are also told, moreover, that Mr. Lupini was identified by a neighbor of the school when, during the night, he left the school through the window carrying a large bag. In the darkness, however, it is difficult to identify someone accurately. It has been estimated, through various experiments, that the chances of correct recognition by night in this context are two out of three.

The experimenter is familiar with Bayes' Theorem because the experiment has been modeled in accordance with this theorem, and she has a calculator at her disposal. It is easy for her, therefore, to calculate the probability that Vicenzo Lupini is the real culprit: only one chance out of three. Given, on the other hand, that few participants know the existence of Bayes' Theorem, that they do not have a calculator at their disposal, and that most of them were confronted for the first time in their lives with such a situation, it was much less easy to them to understand what was expected. In fact, in this kind of experiment most participants would, on the basis of the neighbor's testimony, designate Vicenzo Lupini as the culprit, apparently forgetting that Arsenio Peruggia is the author of the majority of offences. From the experimenter's point of view, designating Vicenzo Lupini corresponds to an irrational behavior.

A limitation of this kind of study is that they are not very informative regarding the way people process information. These experiments tell us what people don't do with pieces of information about probability (Anderson, 2008). They don't tell

us much about what people do with them. In one of the very few experiments specifically designed to examine the way in which participants process probability information–and in which they were given a reasonable chance of understanding what was expected of them–it was found that, in fact, people average the pieces of information (Birbaum & Mellers, 1983). People's typical responses are mid-way between the two pieces of probability information that are provided in the stories. Averaging information in this context is, at least in my view, not that far from being a reasonable behavior.

Another limitation in these studies is that they present people with situations that practically never occur in daily life the way they are depicted in the stories. In daily life, the prior of an event is rarely known with certainty. In daily life, the ability to recognize a person in the darkness is rarely known with certainty. In many cases, the very idea of prior probability seems at odds with the concrete situation (e.g., Gilboa, Postlewaite and Schmeidler, 2009). Finally, and more importantly, in daily life, ordinary citizens are never instructed by policemen to integrate their testimony with prior probability information, to assess the posterior probability, and to report it. Professionals sometimes do that, not ordinary citizen. Is economic science in danger of losing its foundations if people process probability information in a way that does not conform to mathematical principles in situations that rarely (or possibly never) occur in daily life?

Quis custodiet ipsos custodes? (Juvenal)

What can be learned from such empirical studies on human rationality? If an author is disposed to be charitable, he may suggest that human rationality is bounded (Simon, 1997). When the intellectual performance of human beings is compared with the performance of mathematical models in lottery choices experiments or in Bayesian experiments, human performances tend to pale into insignificance. Mathematical models work apparently much better than human beings. But what are we really doing when we compare human's intellectual performances and mathematical models' performances?

First of all, and as illustrated earlier, one compares (a) the performance of a person who is equipped with specialized knowledge (the mathematical model that structures the story) and who has a pocket calculator at her disposal, and (b) the performance of a person who does not know the model used to structure the situation and who, generally, has no access to a calculator. In other words, comparing the performance of a person who has been placed in such a complex situation and that of the model that was used to devise this complex situation, as in the kind of psychological experiments reported earlier, amounts to comparing two human performances.

Furthermore, from where does this knowledge, which ensures the experimenter's comfortable superiority over her participants, come? Is this knowledge extra-human? Obviously, not! The expected value model and Bayes' Theorem are human intellectual productions. When the experimenter uses Bayes' theorem to compute the rational response, she, a human being, implements one of her fellow human's intellectual creation. This experimenter's behavior can, as a result, be viewed as

fully rational, and the experimenter can be credited of having behaved in a full rational way. Can we base ourselves on the experimenter's full rationality for doubting of human rationality?

This situation is highly reminiscent of the Epimenides paradox (Barwise and Etchemendy, 1987). Human beings have apparently been shown not to be rational beings by experimental psychologists working in the field of judgment and decision-making. I am a human being. As a result, I am an irrational being. Are you ready to give credit to my assertion that human beings are irrational beings? Such an assertion, coming from an irrational source (me), is likely to be viewed as highly doubtful, or, in a word, as irrational.

Is there a special category of human beings who are, by special privilege, entitled to decide whether human beings are rational or not rational? Do experimental psychologists working in the field of judgment and decision-making have this privilege? If it is true that these experimental psychologists escape the common law, yes, of course, as rational beings, they are entitled to decide who is rational and who is not. But what happens if they are not? They can, of course, show their findings to incredulous others, but who can decide whether or not they have rationally interpreted them?

''Tell me what your tools are and I'll tell you who you are'' (Assyrian proverb, adjusted)

The heart of the problem is, however, not really there. To understand the problem better, it is necessary to examine the circumstances which have led human beings to create their models. Regarding the expected value model, information about the circumstances of its creation is available (Devlin, 2008). These circumstances put on the stage, in the year 1654, an inveterate game player and amateur mathematician, the Knight of Méré, and two French mathematicians, Pascal and Fermat. Méré wished to know the correct manner to distribute the stakes on hand when a series of games was to be suddenly stopped. To illustrate the problem, let us suppose that two soldiers have signed up to play ten games, that only five games have been played, of which the Soldier A has won four, and that the remaining games cannot be played because of an enemy's sudden attack. How should the stakes be distributed between Soldier A and Soldier B?

Dissatisfied with all the systems of redistribution that had been suggested so far, and aware that his mental capacities as an amateur mathematician would not enable him to solve what, from his viewpoint, was kind of enigma, Méré contacted Pascal. Pascal discussed the problem with Fermat. The two mathematicians solved the problem, each one in his own way, but in a congruent manner. The expected value model was born. At the same time, the concept of probability was invented. Three years later, Huygens generalized the solution suggested by Pascal and Fermat (Devlin, 2008).

What does this example teach us? It shows an inveterate player who is aware that he does not have the mental equipment required to solve a problem that, in his view, is an important one since it implies money. What is this person asking for?

He asks for a handy rule, that is, for a rule that can be easily implemented to redistribute rationally the money on the playing board. The expected value model was thus, before all things, a rule of thumb, a convenient mental tool. If human beings – Méré, Pascal or Fermat – had had the capacity to solve naturally, without any tool, the problem posed by the redistribution of stakes in this context, human beings would never have experienced the need to create such a mental tool; that is, they might never have invented the tool later called the expected value model.

By reversing the perspective now, one can thus suggest that, since the tool called the expected value model was created by human beings, and since this tool is, from times to time, used by human beings, it is very likely that human beings are not naturally equipped with something that would have had the same function as this tool. Human beings invent, step by step, the tools that are necessary to meet their needs, be these needs basic or extravagant. Human beings do not create tools that have already been provided by Nature (e.g., legs), except if these tools have become defective (e.g., artificial legs). From an examination of the set of tools that human beings have created in the course of human history and prehistory, an extragalactic anthropologist, debarking on earth, would have a rather accurate idea of human natural abilities and inabilities even if she has no idea regarding what human beings looked like at the time they used these tools.

Let us take another example of the creation of an intellectual tool. Reverend Bayes wished to find a means to assess the level of God's benevolence towards human beings (Bayes, 1731). The Reverend's intention was to do this by balancing the multiple aspects of terrestrial life that support the idea of His benevolence (e.g., natural love between parents and children) with the multiple aspects of terrestrial life that seem to oppose this idea (e.g., wars and other disasters and diseases). Given the multiplicity of aspects of human life on earth to been taken into account, Reverend Bayes was probably completely aware of the impossibility of mentally producing a suitable balance of these aspects. In other words, he was probably aware that his natural judgment capabilities were not strong enough for him to make a reasonable judgment about the issue. As a result, he decided to think of a mathematical solution to this problem. He thus created the theorem which bears his name. The existence of this theorem is thus a strong indication that Reverend Bayes himself was not Bayesian. If he had been Bayesian, he would not have needed to create Bayes' Theorem. He would just have used his natural Bayesian mind to solve it.

''Man is not like a tool; he is apt to everything'' (Confucius)

The expected value model and Bayes' Theorem are two rational tools. They are human tools in the sense that they have been created by human beings. They have been created as tools that can help human beings in their undertakings. They are non-human in the sense that they were created because human beings are not naturally equipped with the means to solve the problems that these tools were intended to help solving. In Bruner's terminology, they are amplifiers of human intellectual capabilities (Bruner, 1960). Creating mental tools is not an easy task. Creating a Bayesian tool when one is not oneself a Bayesian being may have been a very chal-

lenging undertaking. It may have taken years of thinking. It may have required the collaboration of other people. To explain this creation process, philosophers have at time imagined that these ideas were present from eternity and that they were, in a way, just patiently waiting for people to discover them (Plato, 2009). In their view, creating these ideas could not be a human process. How an ''irrational'' human being could create anything ''rational''?

Both tools – the expected value model and Bayes' Theorem – are just two elements of the rich panoply of tools that human beings have created in the course of their history and prehistory. Some of these tools are mental tools like these ones, and examples of mental tools abound in mathematics, physics, and economics textbooks. Most tools are, however, material tools. They have been created to compensate for the ''limitations'' not of the human mind but of the human physical body (including perceptual limitations) (Bruner, 1960). The flint biface was invented to compensate for human beings' inability to open, using natural teeth and nails, the corpses of animals covered of thick skins. The bicycle was invented to compensate for human beings' inability to travel long distances without quickly becoming tired. The flint biface and bicycle were invented in contexts justifying their need and the possibility of their use.

It would not come to anyone's mind to wonder whether prehistoric humans' teeth and nails functioned like flint bifaces. If they had functioned like bifaces, humans would not have had the need to invent the flint biface. Simple observation indicates that prehistoric humans' teeth and nails did not function *like* flint bifaces, but that humans functioned *with* flint bifaces. Prehistoric humans used flint bifaces when they could make use of them, and they relied on others if they did not know how to use them. Prehistoric humans may probably also have decided, from time to time, not to use flint bifaces. As tools, flint bifaces were at the service of the community of human beings, and not the reverse. In the same way, simple observation indicates that today humans' legs do not function *like* bicycles but that today humans function *with* bicycles. When they need bicycles, they use them. Some human beings, however, have never used bicycles. Using bicycles is not mandatory.

Flint bifaces, bicycles, and Bayes' Theorem are tools of different characters but all three are tools created by human beings to make up for human ''limitations'' (Bruner, 1960). Wondering whether humans' fragile teeth and nails function like flint bifaces or whether human legs function like bicycles seems to be largely meaningless. It would be strange if human beings functioned like their tools, and this idea looks like a joke. In the same way, wondering whether humans' minds function like Bayes' Theorem is probably largely meaningless. Humans' minds function *with* mental tools but not *like* mental tools. If humans' minds functioned like Bayes' Theorem, there would have been no point in creating Bayes' Theorem. As in the case of the flint biface, human beings can use Bayes' Theorem when they have been taught how to use it. Being taught how to use Bayes' Theorem amounts to (a) being told the situations in which using Bayes' Theorem is appropriate, (b) being able to recognize these situations, (c) being able to enter the correct inputs, and (d)

being able to compute the output. When humans don't know how to use Bayes' Theorem, they must rely on others (e.g. professionals).

In summary, wondering whether human beings are Bayesians (El-Gamal and Grether, 1995) is equivalent wondering whether human beings are bifacians or bicycleans. Except for the fun, or for the esthetics of a good title, there is no point in examining such questions from this perspective.

In addition, wondering whether Bayes' Theorem must absolutely be used in all cases that look relevant may also be largely meaningless. Bayes' Theorem is just a tool. As a tool, it is at the service of the community of human beings. Stated the other way, the community of humans is not at the service of its tools, even if these tools are remarkable human creations (Gilboa et al., 2009). As tools, flint bifaces, bicycles, the expected value model, and Bayes' Theorem can be employed each time using them seems to be a reasonable idea. The reverse view is potentially catastrophic. Socio-political theories are mental tools. When they are put at the service of the community of human beings (e.g., for devising financial reforms), they are potentially useful. When the human community puts itself at the service of socio-political theories (e.g., fighting for ideologies), the world is at risk of falling into chaos.

''The surest sign that intelligent life exists elsewhere in the universe is that it has never tried to contact us'' (Bill Watterson)

As stated earlier, the expected value model and Bayes' Theorem are two mental tools. Both tools, both models have the attributes of rationality, despite being human creations, and they are very popular among economists. It is because having rational tools at one's disposal may be of invaluable help under many circumstances that these tools have been, painfully most of the time, created. As already stated earlier, the set of rational tools that have been created by human beings in the course of prehistory and history is not limited to these tools. The important point is that these mental tools have been created in order to inject rationality into human decisions (Keeney and Raiffa, 1976). Rationality is a human creation, and its elements are the expected utility model, Bayes' Theorem, and many other formal models. If rationality had been natural in human beings, they would not have had the need to invent it. Rationality is external to humans in the same way as all other tools – flint bifaces, bicycles, and computers – are external to humans. As far as one can judge, human beings are part of Nature. Nature is probably neither rational nor irrational. Humans are, as a result, neither rational nor irrational. There is probably no point in applying the concept of rationality to Nature or to some of its constituents, be they human beings.

Humans could have been rational beings. If they have been created by an extra-galactic civilization, they could have been equipped, like a Swiss knife, with a great number of mental programs that would allow them to find the easy solution, to the very last decimal, to an infinity of problems like the level of culpability of Vicenzo Lupini or the correct choice between Option 1 and Option 2 in the lottery problem above. On the one hand, this is a grandiose vision-of human beings naturally

equipped with the most modern computing programs, of humans able naturally to approach with full rationality the problems of the universe. On the other hand, this is a distressing vision–of human beings as tools manufactured by members of an extragalactic civilization for the realization on earth of an experiment whose motivations escape understanding. In the absence of data supporting or discrediting this vision, however, this vision could be a reasonable one. Its merit is that it may give sense to our life and existence, which is not to be disdained. After all, finding a reason for living is essential.

If not fully rational beings, human beings could have been partly rational beings. As in the preceding case, they could have been created by an extragalactic civilization, but as their creators feared that humans might become too autonomous not to say rebellious, they equipped human minds with only some computing programs, not all. In other words, humans could have been deliberately created as imperfect tools. They would be the imperfect images of what they could have been if a precautionary principle (Jonas, 1985) had not been applied to them by their extragalactic creators. In this case, a program of research aimed at inventorying the situations in which humans are rational beings and the situations in which they are not, in other words, a research program aimed at inventorying the computing programs human mind has been provided with, and the ones that are missing, would be extremely meaningful. The research strategy described earlier: (a) chose a formal model, (b) create a story that contains the information that forms the ''inputs'' of this model, (c) instruct people to read the story and intuitively assess the output, (d) compute the correct output using the model, and (e) compare the two outputs, the participants' intuitive one and the one that issued from the computation–would, under this vision, make perfect sense.

By implementing this strategy, a full listing of human intellectual deficiencies–that is, a full listing of ''cognitive biases''–could be established (e.g., Hogarth, 1987), and remedies could be considered. In fact, on January 18, 2012, the exact count of these cognitive biases is, according to Wikipedia, 72, from ''ambiguity effect'' to ''zero-risk bias'', without mentioning 32 additional social biases and memory biases. To be successful, such a research program should focus on the discrepancies between human performance in a determined situation and what a normative model of the situation prescribes. This is why the starting point of such a research program should be the available normative models. Situations in which no model exists should be considered as unworthy of examination because they would not tell anything about the extent of human rationality. Focusing on the psychological processes that govern human performance would, for the same reason, be of little interest. Also, examining individual differences in performance would certainly be disturbing rather than helpful.

As already stated, in the absence of data supporting or discrediting one or the other of these two visions, they could be considered as reasonable ones. The second vision has, in addition, the merit of being very attractive to experimental psychologists because it opens a large field of easy-to-do investigations. Would it be just for that, the second vision is worthy of enthusiastic endorsement! Available data from

biology and paleoanthropology, however, tend to support a much less optimistic vision. Human beings would be evolved forms of life (e.g., Prothero, 2007). Human beings would be part of the animal reign. Their name is Homo sapiens. Worse, Homo sapiens would have diverse levels of resemblance to other animals, and even to plants, fungi, and bacteria. As stated above, Human beings would be part of Nature.

Natura nihil frustra facit (Latin proverb)

But even so, what would prevent Nature from providing human beings with a sophisticated set of intellectual tools? This is apparently technically feasible. From time to time, we see on the TV prodigious calculators who can compute the square root of a twelve-cipher number to the last decimal. A well-designed evolution should have been attentive to cleanly separating Homo sapiens from the rest of the troop.

Elaborating on these issues is a risky prospect. It seems that natural evolution, like economists in all epochs, is governed by considerations of costs and benefits. Providing Homo sapiens with a great number of sophisticated mental tools would have been very expensive. (And indeed, Swiss knifes of quality are expensive.) Natural selection requires leaving progeny (not just on survival) and more sophisticated mental tools might not have been selected for if they did not help the person survive and make babies. In other words, providing Homo sapiens with rational mental tools would have made Homo sapiens very bright in the psychological laboratory, but this would probably have been at the cost of survival capacities for this specie. Considering the frequency with which these tools are used under current life conditions on earth, this would have probably been not very profitable. (Very few people use Bayes' Theorem in daily life, and many of them survive until old age without even being aware of its existence.)

Moreover, natural evolution should have provided human beings with the rational tools that have not been already invented, that is, the collection of tools that will be invented during this century and the following centuries. By application of the precautionary principle, providing human beings with these tools is a necessity if one wants human being to adapt to the circumstances of the future (global warming, life on Mars, Berlusconi's reelection), circumstances for which current tools are possibly insufficient.

Nature has, as it were, made another choice; that, surprising, to equip Homo sapiens with no more than coarse physical capacities (e.g., legs), coarse perceptive capacities (e.g., hearing), and coarse mental abilities, such as the ability to add, average, or multiply pieces of information (Anderson, 2008; see also Gigerenzer, Todd and the ABC Research Group, 1999). As already explained, some experimental psychologists working in the field of judgment and decision-making have shown that, in situations in which probability information is provided as the input and probabilistic assessment is expected as the output, people process information in a way that is consistent with the idea of averaging (Birnbaum and Mellers, 1983). Some experimental psychologists have also shown that, in situations in which probability information and value information are provided, people process information

in a way that is consistent with the idea of multiplying (Shanteau, 1974). They have identified, in addition, situations where information processing involves adding (for a review, see Anderson, 2008). In other words, the cognitive ground on which many mathematical models seem to have been built is already present in inherited human mind (Weiss et al., 2010).

More importantly for our purpose, Nature has, as it were, also been attentive at endowing human beings with a meta-tool that makes them able to create material and immaterial tools as a function of the necessities of life, as and when these necessities appear. In other words, one of the main characteristics of Homo sapiens is that she is a tool-maker (Bruner, 1960). For a paleoanthropologist, this statement is a triviality. This creative ability may have seemed extremely puzzling to early philosophers (e.g., Plato), but if one admits, as stated above, that normative models have probably been built on a cognitive ground that is present in human mind as a result of evolution, thus human creativity looks a little bit less mysterious.

From an experimental psychologist's viewpoint, such a vision should rather encourage a slightly different research strategy than the one favored by the vision of human beings created as imperfect images of extragalactic intelligences. As normative models are human tools, and as human tools are usually created as a way of making up for human inabilities, normative models have by definition little descriptive power. Choosing them as starting points for a strategy of research aimed at understanding how humans judge and decide largely amounts to turning ones' back to daily life reality. It also runs the risk of simply accumulating unrelated findings (72 different cognitive biases). These findings are largely unrelated because they are about nothing concrete but are about a discrepancy between a human response, which truly exists and which results from a true psychological process, and a normative model that also exists and results from human creativity. There are more or less as many biases as formal models that have been selected for structuring psychological experiments. What is the psychological relationship between a cognitive bias that is called risk aversion and another that is called base rate fallacy? I am personally skeptical about the psychological reality of 72 different psychological processes. If 500 formal models had been available, no doubt that about 500 cognitive biases would have been found.

Note that experimental psychologists working in the field of judgment and decision-making have not been alone at approaching human information processing from the standpoint of formal models. There are famous precedents. For a long time, developmental psychologists also have endorsed such a stance. For about 40 years, impressive theories explaining human intellectual development or human moral development have dominated the field (e.g., Kohlberg, Levine and Hewer, 1983), until it was progressively realized that choosing formal models as starting points for studying child development leads to nowhere (e.g., Wilkening, 2007).

Under the natural evolutionist vision, the research strategy would rather be: (a) chose a situation that is important for societal or theoretical reasons, preferentially but not exclusively if no normative models of the situation are available (e.g., end of life decision-making), (b) explore the possibly determinant factors that are present in this

situation, with the help of the very persons who are usually engaged in this kind of situation (e.g. professionals), (c) create concrete stories that simulate, as realistically as possible, this situation, (d) instruct people to read the story and respond, and (e) try to model these responses, not by using rigid tools but by using flexible tools, that is, by using tools that are unlikely to impose their structure unduly on people's responses. This is just an example of strategy. There are others that are compatible with this vision, for example, using observational techniques to examine the way judgments and decisions are made in daily life (e.g., Klein and Peio, 1989; Krist, Fieberg and Wilkening, 1993; Hogarth, Portell and Cuxart, 2007).

Of course, this is another way than the one that has been described at the beginning of this article: (a) chose a formal model, (b) create a story that contains the information that forms the ''inputs'', (c) instruct people to intuitively assess the output, (d) compute the correct output using the model, and (e) compare the two outputs. This way does not; however, appear to be an unreasonable one, and many modern researchers in the field of judgment and decision making in particular, and in human sciences in general will easily recognize that their current strategy is compatible with the one that has just been articulated. Anyway, social and personal situations for which no normative models have been created are much more frequent than situations for which normative models have been created.

Such a vision also encourages the development of research about human motivation, human emotions, and human values because these non-normative factors are usually important factors determining human judgment and decision-making in particular and human behavior in general (e.g., Bechara, 2004). Such a vision should, finally, encourage the development of research on human creativity (e.g., Sternberg, 1999).

Also, studying human beings in situations that are close to their natural environment may have many advantages. As advocated by ethnologists, and more generally by scientists working on animal behavior (e.g., Goodall, 1998), the view one can have about an animal's intelligence and sociality can considerably vary whether the animal is observed in the laboratory (in circumstances that are unnatural to it) or in its natural environment (in circumstances in which it has evolved). As human beings would, according to the evolutionary vision, also be animals, this principle may possibly apply to them as well. The view one can have about human's judgment and decision-making abilities can considerably vary whether the human is observed in the laboratory or in its daily life environment.

Under bizarre laboratory situations, all animals, human beings included, often seem to behave in an unreasonable way. In the jungle or in the savanna, it's another story. When there is a chance that the enemy is present, groups of people living in tribes move in single file, with a reasonable distance between each other. This is the best disposition for not being detected. When there is no chance that the enemy is present, groups of people move in packs or in rows. In other words, people in the wild adjust their behavior as a function of a priori probabilities even though nobody has ever told them about the base rate fallacy. ''Unsurprisingly, great apes also adjust their behavior as a function of priors (de Waal, 2005)''.

''Man is greater than the tools he invents'' (American proverb)

If one is of the opinion that human beings are not animals but were created by extragalactic civilizations for known or unknown purposes, then talking about human rationality as a human attribute constitutes a reasonable position. In this view, human beings were created by a superior intelligence, and it is completely possible that they were equipped, among other things, with the tools of rationality. This view is not necessarily disqualified by empirical evidences showing (a) that human beings do not seem to possess all tools of rationality, or (b) that they seem to possess altered, heuristic forms of these tools (Gigerenzer et al., 1999). This view is not necessarily disqualified because, as stated early, extragalactic civilizations probably apply the precautionary principle. Also, if sticking to the opinion that human beings are creatures is, for socio-political reasons, totally imperative, the idea of human rationality can be salvaged by altering the concept of rationality itself. Let us note that, in the19th century, the opinion that humans had been created in their current shape by a superior intelligence was predominant in the Western world, which may explain why the postulate of human rationality was considered as a foundation of economic science, without further examination.

If one is of the opinion that human beings are naturally evolved forms of life and not tools created by superior intelligence, then talking about rationality as a human attribute is more disputable. Of course, natural evolution could have equipped human beings with mental programs that would allow rational behavior either under certain conditions or in most circumstances. But being of the opinion that humans are evolved forms of life also supposes sensitivity to available scientific evidence. In this view, and as stated earlier, flint bifaces, bicycles and normative models are tools, material or immaterial. These tools were created by reasonable but not necessarily rational beings. Reason is not a human creation. It's something that human beings have in common with many other animals; that is, reason is part of our inherited patrimony. Reason is, indisputably, an attribute of human beings. Reason is, among other things, what allows human beings to join their efforts and create intellectual tools that possess the attributes of functionality as in the case of flint bifaces or the attributes of rationality as in the case of mathematical models. But reason is also an attribute of many non-human beings. Reason is, among other things, what allows non-human animals to also use tools if not to create them (e.g., Goodal, 1998).

Moreover, since rationality is an attribute of intellectual tools, rationality is subordinated to reason, which is an attribute of tool-makers. It is because we are reasonable beings that we can decide not to use rational tools to solve a problem when we think that these tools, despite their attractiveness and power, and despite professional customs and traditions, are definitely not appropriate (e.g., Gilboa et al., 2009; Montgomery and Adelbratt, 1982). It is because we are reasonable beings that we can decide to discard available evidence supporting the view that humans came into being through evolution and stick to the view that they were created. - People may reasonably keep the traditional view if they avoid uncertainty and feel their mental health would be endangered if they adopt the new view, or if they find

themselves strongly committed to the traditional view, or if they fear their morality would be shaken if not anchored in firm principles. It is because we are reasonable beings that we can wish that considerations of love be put at the heart of the economy in place of financial considerations, that is, in place the usual, not to say rational, costs and benefits analysis (Beretta, 2011).

Being reasonable is just taking into account the many circumstances before acting; that is, acting ''at the right times, on the right grounds, towards the right people, for the right motive, and in the right way'' (Aristotle, 2004, p. 41). The precautionary principle (Jonas, 1985) is anchored in human reason, not in the rationality of human tools. This is probably why political decisions that follow from the application of the precautionary principle are not always well understood by technology experts. Their rational risk analyses – risk analyses based on the most sophisticated models – seem to be ignored by politicians even though they demonstrated, for example, that, in some particular situation or regarding a particular technology, risk was minimal or nonexistent. The experts sometimes think that rationality can, and even should, supersede reason, that rationality is boundless.

I wonder, however, whether the reasonable view about rationality would be that it is in fact always bounded. For instance, the rationality of Bayes Theorem can be viewed as limited to situations in which a priori probabilities can be, at least vaguely, assessed (Gilboa et al., 2009), and the rationality of past risk assessment at Fukushima nuclear plant was certainly limited to a range of well-know situations. As far as I can judge, ''bounded rationality'' is a tautological expression. (Is there a specialist of Gödel's thinking in the plane?)

If one is of the opinion that human beings are evolved forms of life, a reasonable option would be to propose that economic science is not based on the postulate of human rationality, but on the reality of human reason. This is not to say that humans are always behaving in a reasonable way. This is just to ''postulate'' that, most of the time humans have defensible reasons for behaving the way they behave. Understanding these reasons may be one of the objectives of social sciences in general rather than systematically trying to fit behavioral or judgmental data to rigid a priori models or to fix things until the model fits the data.

Note, before ending to read this section, that being of the opinion that human beings are evolved forms of life does not imply anything about the origin of the universe. It just implies that human beings have not been created in their present shape by a superior intelligence, what can be called ''lay creationism''. Lay creationism much be distinguished from sophisticated creationism (Behe, 1996): there are many questions about Nature that current evolution theory has left largely unexplained (e.g., in the domain of biochemistry).

''In memoriam Bernard Mandeville'' (Captain Picard)

Are normative models to be avoided in economic science? Not necessarily. Of course, when pushing their caddies in the supermarket, human beings tend not to employ the tools of rationality that have been created for their use. Of course, when launching the production or the commercialization of a new commodity, companies

do not always analyze the market in a reasonable way. In other words, economic agents are not always either reasonable or willing to employ rational tools and as a result choose in a rational way.

The psychology experiments reported at the beginning of this article have studied the behavior of individuals grappling with laboratory situations. Economic science, on the other hand, is, at least in part, about populations of individuals and their real consumption choices. (Of course, there are branches of economic science that are about individual behavior, and there are other fields in economic science that do not specifically examine consumption, e.g. the economics of marriage.) One can think that if all individual consumers or at least a vast majority of them behave in a way that is rational, then, on the level of populations of individuals, rational laws will be detectable. One can, symmetrically, think that if, on the level of populations of individuals, economic laws presenting the attributes of rationality can be identified, this means that a majority, at least, of individual consumers have behaved in a rational way, economically speaking.

Within this framework of beliefs, it seems logical to think that if someone can show that human beings are not rational beings or worse, that rationality is not an attribute of human beings, then the rational laws found by the economists are most probably based on illusion. How could a vast set of irrational behaviors produce economic flows that economists could model using rational tools? It is, however, not impossible that million ''irrational'' individual behaviors can lead, on a higher level, to the observation of phenomena presenting sufficient regularities to allow mathematical modeling using rational tools.

One speaks in such cases of ''emergence''. Emergence phenomena are familiar to physicists (Laughlin, 2005), and the idea of emergence is not new (Lewes, 2004). Most of us are not physicists, but all of us are familiar with a certain number of physical laws that govern our sensible universe. These laws of physics, known since a relatively long time are called Newtonian law. In good logic, Newtonian laws should govern all physics. It turns out that not. The domain of validity of these Newtonian laws stops, however, at the level of subatomic particles. At this level, a radically different set of laws apply, quantum laws. From them, absolutely nothing can be predicted regarding our sensible universe. Quantum and Newtonians seem to belong to ''different universes'', which is a puzzle for lay reductionist thinking.

If one thus admits that there exist possibilities of discontinuity in the manner of explaining physics phenomena, why not admit possibilities of discontinuity in the manner of explaining phenomena in the social sciences? Of course, the parallel between quantum laws versus Newtonian laws on the one hand and individual versus collective level on the other hand has no pretention of being a literal one. Individual consumers are not particles. What in fact matters is that we realize that from one level of observation to another, radically new laws can emerge, and this can occur not just in physics but also in economic science or in psychological science. Can the functioning of neurons can fully explain Leonardo's paintings?

If this point of view is correct, it becomes possible to admit the possibility of

finding rational laws at work on the level of aggregates of individuals, while at the same time each individual's behavior would be far from conforming to rational models. In economic science, the emergence of collective rationality from very simple ''almost stupid'' individual behaviours has already been widely studied, and the very idea goes back to Mandeville's fable of the bees and Adam Smith's invisible hand (Smith, 2000).

The point on which I want to insist, however, is that the possible existence of emergence phenomena in social sciences makes unnecessary the idea that economic science inevitably rests on the postulate of human rationality, be it ''natural'' (the intelligent design option) or resulting from the economic agent's reasonable use of rational tools (the natural evolution option). That human beings are rational beings or are not rational beings might be an irrelevant issue for economic science. Belief in its relevance might be a byproduct of lay reductionist thinking coupled with lay creationist thinking.

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