FROM BOUNDED TO EPISTEMIC RATIONALITY: TOWARD A THEORY OF RATIONAL DISCOVERY*

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* *Earlier versions of this paper were presented by the author in seminars at Pompeu Fabra University, Harvard Business School and Berkeley, Haas School of Business and revised during visiting scholar periods at the University of Chicago and Stanford University during the 2004-2005 academic year. Colleagues at these institutions are warmly thanked for the occasions of discussion, in particular Robin Hogarth, John Padgett, John Freeman, Jim March, Jerker Denrell, DanielBeunza, Giovanni Gavetti. The support of Bocconi funds for base research to this project is acknowledged.*

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Abstract

This paper criticizes the divide 'by assumption' between rational choice and behavioral choice and proposes a way of reconnecting 'bounded' and 'unbounded' rationality. The connection is an epistemic model of rational discovery and problem modeling which can complement both the descriptive behavioral models of search and choice and the prescriptive model of rational choice. The concept of epistemic rationality is an answer to the question of how the knowledge on which any form of rational choice is based can be rationally constructed. It is also argued that the concept of epistemic rationality, and the operationalized models that can be developed by using it, can also provide a missing cognitive foundation for a variety of relevant economic behaviors and structures, such as exploration, innovation, strategy formulation, nearly-undecomposable structures, governance by communities, and design.

INTRODUCTION

How do new strategies and structures get discovered? Where do innovation in technology and products come from? How can economic actors *improve* their approach to those exploratory decision processes? Paradoxically, neither one of the two major paradigms about rationality in economic decision making is able to respond to these core and simple questions that any decision maker faces daily and which are so central in the currently much emphasized 'knowledge based' economy.

In fact, the analysis of rationality in economic behaviors, at individual and organizational decision making levels alike, has come to be divided into two main 'approaches': the 'rational choice approach' typically 'assumed' in the majority of economic research, rooted in the 'Savage paradigm' (Savage 1954); and the 'behavioral approach' typically ‘assumed’ in the majority of organizational, behavioral and administrative science research, and rooted in the ‘Simon paradigm’ (Simon 1951, 1955). There have been models ‘integrating’ the two views, most notably those constituting the area of ‘behavioral economics’. However, these ‘connecting models’ basically contaminate the two basic models, mixing some elements of each: inserting behavioral parameters as risk aversion, regret, identity etc., and/or search costs, in utility functions (Tversky and Kahneman 1974; Thaler 1991; Akerlof and Kranton 2000; Rabin 2002; Oaksford and Chater 1998) or interpreting behavioural strategies as deviations and ‘biases’ from rational choice (Kahneman, Slovic and Tversky 1982). Rather, the proposal advanced here is to develop a new model, which is somehow ‘intermediate’ between the rational choice and behavioral traditions, not because it mixes the two, but because it sheds light on the rather unchartered, but most interesting, territory lying between the ‘rational’ and the ‘behavioral’ models of decision making, the territory of logically sound, or ‘rational’, discovery.

To get there, some revisiting of the meaning and definition of core terms such as ‘rationality’ and ‘heuristics’ will be needed, together with a criticism of the distinction at the origin of the economic/behavioral divide, namely the very distinction between ‘bounded’ versus ‘unbounded’ rationality. The first Section ‘A criticism of the bounded/unbounded rationality divide’ is dedicated to this. The second section ‘An epistemic model of rational discovery’ explains why a model of epistemic rationality can reconnect the behavioral and economic models of decision making in the stronger sense of providing a missing complementary model of rational discovery; and sketches the features that models of decision making and problem solving as rational discovery could have. The third section develops testable implications and propositions as applied to relevant innovative economic behaviors as technological innovation, strategy making and organization design; and revisit available empirical evidence that could be better interpreted by a rational discovery model rather than by both ‘behavioral search and choice’ and ‘deductive rational choice’ models. In particular, it is shown that epistemic rationality can provide some missing cognitive foundations for understanding innovation related phenomena such as ‘exploration’ (rather that local search) (March 1991), ‘epistemic communities’ (rather than ‘communities of practices’) (Cowan, David, Foray 2000); and can provide an account of why and when organizations are and should be nearly-*un*decomposable systems, rather than nearly-decomposable systems (Simon 1969). The concluding Section highlights the implications of extending the behavioral theory of the firm to an ‘epistemic’ theory of the firm, and the ‘knowledge based’ view of the firm to a ‘knowledge growth’ (or ‘discovery based’) theory of the firm.

A CRITIQUE OF THE BOUNDED/UNBOUNDED RATIONALITY DIVIDE

The concept of bounded rationality and the ‘behavioral model of rational choice’ (Simon 1947, 1955, 1979) have often been presented and received as a ‘more realistic’ theory of human decision making, based on more accurate and corroborated descriptive ‘assumptions’ on computational capabilities and on the amount of information that can be processed, with respect to the supposedly ‘omniscient’ and ‘complete knowledge’ assumptions characterizing the rational actor paradigm of economics. This emphasis on descriptive realism appealed to social scientists in psychology and sociology, but limited its significance for economics and, I submit, also its potential for organization science. In fact one shared interest of organization science and economic theory is understanding and predicting solutions (actions, structures, processes, arrangements) that are better than others (a concern with superior, rather than just frequent, behaviors). The behavioral tradition drove research efforts toward studying ‘real’, ‘actual’ ‘normal’ and ‘frequent’ behaviors; incurring a significant loss of concern in finding and modeling relatively ‘superior’ behaviors, albeit different from deductive utility maximizing. Furthermore, bounded rationality based research has ended up focusing less and less on ‘intendedly rational’ behaviors (the best one can do given the state of uncertainty) to focusing on everything that is actually done, right or wrong, in the face of uncertainty, including mistakes, biases, illusions and shortcuts of heuristic rationality with respect to classic expected utility maximizing (Tversky and Kahneman 1982); or on developing models of behavior guided by rather ‘conservative’ search rules, as ‘local search’, ‘routines’, ‘linear decision rules’ and ‘rules of appropriateness’ (Cyert and March 1963; Nelson and Winter 1972; Lindblom 1959; March 1994). The ways in which recent attempts at blending psychology and economics have been conducted – welcome and sane as they are – have however been mainly inspired by this ‘quest for realism’. This is indeed useful for better prediction of actual, normal, average economic behaviors. It is less useful for improving those behaviors without resorting to standard rational choice when its assumptions are not applicable.

In spite of these limits, which the perspective advocated in this essay wishes to help in overcoming, the innovative idea of the bounded rationality and behavioral research tradition, retained and developed here, is not so much that of producing ‘realistic’ models, but that of modeling decision behaviors viable under conditions of uncertainty exceeding the requirements of utility maximizing models; and, for that very reason, the idea of modeling 'search' rather than (or more than) choice. On these grounds, the bounded rationality tradition posed not only a problem of *information costs and computational complexity*, but also the problem of the *origin, validity and reliability of knowledge* on which any non-random choice is based (where do alternatives, states of the world and consequences come from, how are they discovered and tested) (Grandori 1984; Loasby 2004). It has been argued that while the first component of rationality can be largely accommodated within a rational choice framework, the latter component of rationality has been, so far, out of the scope of rational choice theory (Shackle 1972; Tirole 1999; Radner 2000). The question addressed here is whether the conditions of 'strong', 'thick', 'epistemic' or 'Knightian' uncertainty, that are usually thought to lead to a shift from a 'rational actor assumption' to a 'bounded rationality assumption', cannot be better treated in a different way, trying to respond to the question: what rational strategies are available if a problem is not structured? Is there anything like rational problem structuring and modeling?

In order to address this question it seems useful to highlight first why the bounded rationality and behavioral tradition has not so far been able to do so.[1]

- *The overlooked distinction between information cost and knowledge validity.* A standard criticism of bounded rationality in economics is that 'satisficing' is a form of optimizing in which the costs of search have been factored in. And in fact, if problems are structured, i.e. the classes of relevant alternatives and the classes of relevant objectives are known, then this is very much likely to be the case (Baumol and Quandt

1964; Young 1998). In that light, Simon's much cited example of searching for a needle in a haystack, sharp enough to sew with, seems to have been a misleading example, because the ordinal judgment that the marginal costs of search are greater than the marginal benefits can be made in this case. And there is no question that needles are 'causes' of the effect of 'sewing', they have been designed for that very purpose, so there is little uncertainty about the cause-effect relationship. As it is now largely accepted, the interesting difference between 'satisficing' and 'optimizing' arises only if problems are unbounded, unstructured, i.e. the classes of potentially relevant alternatives and consequences are non numerable infinite; and if knowledge is fallible, i.e. the description of observed alternatives, and the theories of cause-effect relationships between actions and consequences are conjectural (Grandori 1984; Gigerenzer, Selten 1999; Arrow 2004; Baumol 2004; Loasby 2004). But if so, then the difference is mainly one of domain: 'utility theory' is a theory of choice, 'assuming' that inputs are known; 'bounded rationality theory' is mainly a theory of search for those inputs.

A corollary of this characterization of the two traditions is that they should not be treated as 'rival assumptions' on behaviors (Grandori 2001). Rather, utility maximizing choice and acceptability based search are decision strategies which solve different problems in decision making – problem modeling versus action selection. The missing piece of the puzzle is a model of possible and superior search behavior, which complements the presently available models of 'normally flawed' search behavior.

- *A hyper-rational characterization of economic rational choice.* The conventionalist 'assumption' of economics that inputs are known, has slowly been transformed into the claim that economic models assume that knowledge is actually complete and infallible. Most behavioral scientists as well as many economists seem to have started to believe that the admission that knowledge is fallible and that actors do not have perfect foresight, amounts to abandoning the rational actor paradigm for accepting a bounded rationality 'assumption'. Simon often used the word 'omniscient' to characterize the 'economic model of man', and economists write things like "with rational agents contingencies are never unforeseen, they are at worst indescribable" (Tirole 1999:756). By contrast, I am here arguing that, logically and philosophically speaking, there can be no such thing as complete knowledge and perfect foresight, but that, at the same time, this does not imply that that actors cannot be rational if they know that they are not omniscient, and that value maximizing calculations are not feasible and. In fact, they are made. The characterization of rational choice as a model of 'substantive rationality', in which 'all possible alternatives' are considered, and a payoff function is defined upon each of all the possible outcomes of choice is a caricature; leading to the statement that value maximizing is empirically impossible ('there is no evidence that, in actual human choice of any complexity, these computations can be, or are in fact, performed' – Simon, 1955:104). I submit that, instead, there is plenty of evidence that actual human beings, even in choice situations of considerable complexity, manage to select relevant information and to structure problems so that they can be dealt with a *value maximizing strategy*, reaching remarkable and reliable results (making airplanes fly, calculating insurance premia or optimal production and transportation schemes); but that, at the same time, it is true that no claim of objectively complete knowledge and *absolute optimality* can be made about those solutions. Value maximizing and complete objective knowledge are two very different things, and they have been improperly collapsed. Optimal solutions are entirely possible within a stylized, selective model of a situation, either as the problem of finding an equilibrium with posted prices, where firms have to choose only levels of production, or as the problem of finding an optimal path in a given transportation network. In fact, if we were to consider the value maximizing models crafted by economists as empirical material for supporting the above statements, we would observe that they are usually very selective and stylized models, considering very few alternatives and very few possible states of the world in order to be able to make value maximizing calculations; rather than models that take into account 'all possible' dimensions of action, alternative actions, and contingencies. Even theoretically, in the founding formulation of the rational choice model, Savage (1954) was asserting "the necessity of confining attention to, or isolating, relatively simple situations in almost all applications of the theory of decision developed in this book". In other terms, value maximizing decision behaviors (whether modeled or actual) are complementary with stylized and simplified problems, not with omniscience. In that sense they imply 'heuristics' for simplifying the world no less than any other problem solving approach (including scientific discovery).[2]

- *A repertory of low powered 'heuristics'*. The term 'heuristic' comes from the Greek '*eurisco*', meaning 'to find, to discover'; and in the logic of science 'heuristics is that part of a science that has as an object the discovery of facts or truths', the 'very method of research' (Lakatos 1976). Hence, in modern epistemology the term heuristics indicates a discipline, the logic of discovery. By contrast, the notion of heuristics in behavioral decision theory has come to indicate a search shortcut, a ‘rule of thumb’, or even a flawed method with respect to rational standards (Kahneman, Slovic and Tversky 1982). The repertory of heuristics thus identified in the behavioral tradition include precisely those ‘methods’ that none would recommend as superior methods for discovery (and that, in fact, are recommended to be ‘corrected’ or ‘debiased’): judge frequencies by ‘availability’, assign probabilities taking into account ‘representativeness’, making estimates by ‘anchoring’, be ‘over-confident’ in own hypotheses…. However, heuristic rationality has another component, strong rather than weak, logically correct rather than biased, and nevertheless not ‘maximizing’ for the simple reason that the purpose of that form of rationality is to discover the facts, consequences, alternatives, laws of cause-effect on which choice is based in a valid way, rather than that of selecting alternatives according to anything that can be maximized. It is to the analysis of what the mechanisms of this type of heuristic rationality are, to constructing a repertory of ‘highly powered heuristics’, that our work is devoted.

AN EPISTEMIC MODEL OF RATIONAL DISCOVERY

The term ‘rationality’ comes from the Latin word *‘ratio, rationis’*, ‘the principle governing knowing activity’, and something is rational if ‘it proceeds from reason’, ‘is founded on logically sound procedures, on scientific method’ and this is the meaning of the word rationality in logic and philosophy of science. The opening phrase of Simon’s *Behavioral model of rational choice* (1955:99) states that “traditional economic theories postulate an ‘economic man’ who in the course of being ‘economic’, is also ‘rational’ ”. The two properties are different, in fact. ‘Being economic’ [3] has to do with resource saving, with balancing costs and benefits, hence with motives and interests ; while 'being rational' has to do with using valid and reliable information, making proper inferences, considering proper alternatives, hence with knowledge and logic.

The main 'limit' of the classic rational choice model, in this light, is that it focuses almost entirely on interest and almost nothing on knowledge (Shackle 1972). The notion of rationality employed in rational choice theory is restricted to mean 'logical', 'consistent', 'deductively correct', but it does not include rationality as a systematic, valid, sound method for constructing the knowledge on which decisions are based; it focuses on the deductive component of rationality , not on its heuristic component .[4] On the other side, as said, the bounded rationality and behavioral tradition does focus on the generation of knowledge, but not at the best of human cognitive possibilities.

There is a hole then: a theory of rational discovery is missing. It seems reasonable to construct such a theory on the basis of what we know on the nature of knowledge and discovery, and more precisely on available theories of rational discovery. On these grounds, if we have come to know something from the centuries of philosophical and epistemological debate on the nature of knowledge and the logic of discovery, even in its more rationalistic schools, it is that there can be no such thing as complete and infallible knowledge (Russell 1948, Popper 1935, Godel 1931). This proposition from philosophy of science, is strikingly at odds with the 'assumptions' attributed to the economic model of rational choice (also by its critics). The argument I am advancing here is that rather than 'rejecting' economic rational choice as 'impossible' and 'unrealistic' because of those assumptions, we should modify (or reinterpret) those uncomfortable assumptions so as to make them meaningful and rational (even before making them realistic). In fact, the logical status of statements such as ‘all possible alternatives are considered’, or ‘all possible states of the world are conceived’, or ‘all possible contingencies are foreseen’ is that they are meaningless, logically impossible, not rational. The argument may well be the same which led Popper to demonstrate that the probability that a scientific (empirical) theory is true is always zero, because the set of potential falsifiers is always infinite. By the same token, the likelihood of having conceived ‘all’ possible alternatives or ‘all’ possible states of the world is always zero because they are infinite not only in number, but most importantly in kind.

In this light, value maximizing can be seen as a set of rational procedures on how to compare alternatives according to interests, and as an entirely possible and wise strategy, but, at the same time, as a strategy that *cannot* be based on perfect foresight and complete knowledge (non rational statements); rather it can and should be based on a valid, corroborated theory or model of the problem at hand, on rational discovery, on a set of rational procedures on how to acquire knowledge.

This view of rational choice, albeit different from the usual current interpretation of it in economics, is consistent with the original formulation of its foundations. In fact, Savage’s requisites for rational choice, do not include any demand for ‘completeness’ of knowledge, but rather, and by contrast, that an acceptable, highly simplified model of the world is defined, valid for guiding action in the ‘grand world’ (see more on this below); and do include (allow) ordinal and partial preference functions (see also Sen 2002, on this).

A corollary of our reinterpretation of rational choice is that all models of rational choice are procedural, sets of methods. If there is no infallible knowledge, there is no substantively rational choice, i.e. able to guarantee that an objectively optimal solution is determined. In other words, we should also abandon the characterization of economic rationality as 'substantive' versus other forms of rationality as 'procedural' (Simon 1976). All forms of rationality are procedural, in our revised terminology.

As it has been possible to generate a variety of models of decision behavior (satisficing, incremental, appropriateness based etc.) from the concepts of bounded rationality and behavioral heuristics, it should be possible to generate a variety of models of decision behavior from the concepts of epistemic rationality and rational heuristics. Here, I am going to outline some common ingredients of any such model, and to outline a model of rational decision making as scientific discovery.

The elements entering an epistemic model of rational decision making can be stated as follows. [5]

A problem model is a set of hypotheses on cause-effect relationships, where alternatives are causes and consequences are effects, valid under some conditions (sets of states of the world or events) (e.g. analytical skills predict performance in high education programs in science based degrees; investments in IT increase decision making quality/efficiency if decision makers use them; information disclosure attracts investments if investors reads reports; etc.)

In general, as both Simon and Savage stated, a problem model includes a 'set of alternatives that an actor can conceive', a set of consequences that can occur under a set of conditions or 'states of the world', and a set of information describing the above elements. The assignment of probabilities sophisticates the model, but is not a necessary ingredient of rational choice, and actually, we are going to argue, in conditions of epistemic uncertainty it is rational to not assign them at all; much in the same way as a good part of game theory employs maximin or minimax strategies , that are defined irrespectively of probability assessments.

In addition, and beyond what both Simon and Savage envisaged, what enters a decision process is not just 'information' on alternatives, contingencies and outcomes, but conjectural knowledge or 'hypotheses' on alternative-outcomes relations *(h)* (e.g. 'incentives increase motivation') and even on information or 'observational propositions' *(i)* (e.g.' this is an incentive', 'this person is highly motivated'). So the core elements entering any model of rational decision making including rational discovery are: *a* (alternatives, actions, options, causes); *s* (states of the world, contingencies, conditions); *f* (consequences, effects, outcomes); *i* (information on *a, s, f*); *U(f)* (utility or value of consequences); and , eventually, probabilities attached to any of the other elements: *p (f)* (probability of consequences, conditional both on the probabilities of contingency conditions *p (s*) and on the probability that an action a is taken *p(a)*); *p(i)* (confidence in the accuracy or truth of information *i*), and *p (h)* (confidence in the validity or truth of hypotheses on cause-effect relations between *a* and *f*); and even *p(u),* probabilities that any valued consequence or objective turns out to have utility *u* . Finally, a cost of experimentation and research term C_{ih} can be added; it represents the costs of data gathering and hypothesis testing, and it should be clearly distinguished from the degree of confidence (or probability) in the gathered information and in the constructed hypotheses (if they can be assessed).

- *Procedures for generating and testing cause-effect (a/s/f) hypotheses.* Paradoxically, the search and testing rules identified in the 'behavioral model of rational choice' - search until a satisfactory alternative is found, change the set of alternatives only in the face of failure, and 'lower' or 'raise' aspiration levels as a function of the ease of findings - have some claim of rationality as testing procedures only in structured problems with known classes of alternatives, not in the unstructured problems where bounded rationality is supposed to be particularly interesting. If we know we are searching for a needle capable of sewing, and we can judge that no matter which particular needle will come up, its marginal added value in sewing capacity is negligible, then it is rational to stop searching. But if we are trying to discover which the potentially relevant sets of alternatives are (needles or other machines) and which relevant streams of consequences they would bring about (sewing, reselling needles, melting needles…)[6] then further and deeper research is superior.

More generally, research on the possible sets of alternatives (causes) A', A''…and the possible sets of states (events, conditions) S', S''…that may cause F', F"… is a superior heuristics.

In sum, rational search under strong uncertainty would not lead to modelling problems as sets of particular actions with a precise and finite set of consequences. Problems should be modeled as unbounded sets of options (usually involving some allocation of scarce resources) characterized by unbounded streams of possible consequences. [7]

When is a problem model acceptable? A notion of acceptability is needed here; however, it does not apply to payoffs, it applies to propositions. In science, as we all know, we face a variety of 'acceptability decisions': accept observational propositions as correct representations, accept cause-effect proposition or reject them, accept 'ceteris paribus clauses', and try to avoid 'type I' and 'type II' inferential errors (accept false hypotheses and reject true ones) (Lakatos 1976; Einhorn and Hogarth 1978). Savage himself (1954) comes to the question: when is a problem model 'satisfactory'? Does he respond with the impossible prescription: when 'all' possible alternatives and states of the world have been included? By no means. He responds: a problem model is satisfactory (acceptable) if the utility judgments over the alternatives and consequences within the 'small world' of the problem model do not change if transferred in the 'grand world' of reality: i.e. a 'small world' is an acceptable partition of the 'grand world' if the utility ordering of alternatives' consequences in the partition is the same as it would be in the grand world [U(f) = E(f)] [8]. The requisite has nothing to do with maximizing per se; it has to do with the predictive validity of the small world model for behaviors in the grand world. Maximizing enters the picture if consequences have value and research has costs. Then, the costs of research and the possible decreasing marginal returns of exploration in any area of action do intervene in setting upper bounds to problem model expansion and investments in research.

Translated into a rational research heuristics, this criterion would amount to a prescription of including in the problem model any alternative with significant hypothesized correlation with the considered consequences, and any alternative with significant interdependence with other alternatives (complementarity, substitutability). This is an empirically relevant, applicable, rational way of *constructing* (rather than assuming) *problem models* characterized by properties which may *make* choice more rational. In other terms, alternatives can be, often are and should be researched and crafted so as to be amenable to valid and reliable judgments about their relative superiority. For example, in the choice of which product to launch, or which new project to invest in, research can be applied to develop solutions whose stream of consequences can be judged to be superior to other courses of action, and whose worst possible outcomes are compatible with resource constraints (and better than in other options), 'no matter what' the state the world is. This proposition leads us to address the issue of *if* and how probabilities may be rationally defined.

- *Procedures for generating and testing hypotheses on probabilities (p).* If and once a model of relevant events is constructed, then probabilities can (eventually) be attached to them. The mode of testing probabilities depends on what type of probability judgments are involved – a priori, frequency based or estimates (Knight 1921; Savage 1954; Popper 1935).

In the case of a priori probabilities, defined by the structure of possibilities in a logical way (i.e. the dice), they can be logically deducted rather than tested.

In the case of structured problems, where judgment on *p* is difficult, but all other elements are well defined in the problem model, the calibration of probability judgments on the basis of the observation of frequencies is a rational heuristics for testing and revising probabilities in repeated decisions, and the construction of lists of favorable and unfavorable reasons for the event at hand is so for unique decisions (Lichtestein, Fishoff, Phillips 1982)

In a larger part of cases, however, estimate based probability judgments are needed (what's the probability that the prime rate interest increases, or that purchases will increase if a certain marketing action is taken etc); and in the perspective of rational discovery it is meaningful to ask how they can be improved or well-estimated rather than poorly estimated. As known, Bayesian inference models are rational heuristics in that realm. According to Bayes' law, the posterior probability of a hypothesis h_j, given some new information i, $p(h_j / i)$ is equal to $p(h_j)\, p(i/h_j) / p(i)$. But ordinal Bayesian judgments are also possible – does the confidence in a hypothesis increase or decrease on the basis of new information – and applicable to situations in which a punctual evaluation of probability has no basis.

However, many if not most scientific as well as economic problems are still less structured than those amenable to Bayesian learning. Probabilities may be 'unknown' (Knight 1921), in the strong sense that assigning them would be a shot in the dark, a non rational strategy, no matter what 'new information' may come up: for example, assigning a subjective probability to a hypothesis belonging to an infinite set, and with infinite possible falsifiers; or to assign probabilities to other players' moves in interactive situations where there are incentives to change move contingently to what we think other players think that we think…etc. In fact, scientists in most cases do not specify the probability of their theories being true (and are advised not to do so), and game players do not judge the probability of other players making specific moves (and are advised not to do so). In spite of that, hypotheses can be rationally tested. And alternative strategies can be compared in terms of their relative superiority, if the streams of consequences following from them are Pareto-rankable independently of a prevision of which state of the world will occur with what probability. What if they are not rankable? As already observed, the rational decision maker will generate, construct, *design alternatives that are rankable irrespectively of the states of the world,* courses of action about which these judgments can be made.

- *Procedures for generating and testing preferences (U).* Is there any way to 'discover' preferences rationally or at least to define preferences so as to allow rational discovery of actions? This is the hardest terrain. Elster (1983) and Sen (2002) provide a starting basis as they have argued that the prevailing notion of the rationality of preferences in economics is 'thin' or 'narrow' as confined to 'logical consistency', and we would need a 'broad' theory of rationality in preference formation (a totally consistent, actually homologous argument to that made here about problem modeling). This question invites to try to enlarge the set of 'procedures' beyond logical consistency, and find a way to link preference definition to experimentation in a sound, valid way. And this is the road we shall try to follow, avoiding the more traditionally followed, but very slippery, (Weberian) road of trying to evaluate the content of value judgments, to discriminate between more or less ‘rational’ preferences in terms of content (a ‘substantive rationality’ criterion applied to preferences).[9]

A first rule for defining preferences rationally is directly linked to Elster’s and Sen’s elaborations and highly related to the criticism and revision of Simon’s model of satisficing behavior undertaken here.

The core mechanism of preference definition in Simon’s model (1955) is ‘aspiration level adjustment’. Simon (1955: 104-105) introduced the notion of aspiration levels by noticing that both in economics and psychology there is the notion of a ‘lower bound’ to acceptable payoffs, and “that in psychological theory we would fix the boundary at the aspiration level; in economic theory we would fix the boundary at the price which evokes indifference” between transacting or not (i.e. at the ‘reservation price’) . To this point, both the economic and the behavioral model of rational choice admit that to fix these ‘lower bounds’ to payoffs is a rational heuristics, necessary to formulate judgments of ‘rejection’ or ‘acceptance’ of alternatives .

The behavioral and economic tradition widely diverge, instead, as to how to formulate and adjust aspiration levels and on what to do with the alternatives which are ranked as superior to reservation or acceptable values. In economics the notion of reservation price is an opportunity cost concept, the lower bound is given to the best available alternative to any considered alternative, supposing that the ‘best alternative’ is known (Raiffa 1982). The behavioral tradition, supposing that alternatives, let alone the best ones, are not known , aspirations levels are supposed to adapt empirically to what is found, ‘raising’ or ‘falling’ as a function of the ‘easiness’ (frequency, estimated possibility) of finding. The question is : is this an ‘intendedly rational’ heuristics? Apparently not,

unless what is adjusted is only the probability of finding rather than the value itself. In other terms, an intendedly rational heuristics should at least conceive the aspiration level as composed by an 'expectancy' and a value or 'valence' judgment (perhaps as in the expectancy/valence models of motivation). Expectancies, or confidence, or probabilities that enter into such aspiration levels as 'lower bound expected values' can be adjusted on the basis of observed frequencies of finding, not values. Otherwise, a judgment on what is possible to find or reach (a proposition on cause-effect relations) would be mixed with a judgment on what is desirable to reach, and it would entirely falls into the category of 'sour grapes fallacies'. In addition, the downward adjustment of aspiration levels is the main driver of resignation to conditions of deprivation or otherwise to poor opportunity structures [10] (Sen 2002). Furthermore, there is nothing irrational in 'desiring' or assigning high utilities to actions and achievements that are currently judged as very low probability events, and even almost unreachable outcomes. Actually, this is the very mechanism sustaining radical discovery, as far as preferences are concerned: if Leonardo da Vinci, and the Wright brothers after him, hadn't preserved their judgment of the high desirability of flying, in spite and along with the judgment that it was very difficult to achieve, we would never have had airplanes.
Hence, *distinguishing possibility judgments and value judgments* is a first procedural rule for defining preferences in a rational discovery perspective.

Second, *distinguishing interests from orderings of alternatives* is another heuristics for preference formulation which may be claimed rational. It is common in economics to think of 'preferences' as 'orders' defined over alternatives. Although everything that is done in economics has gained the status of being rational by definition and by assumption, it is clear that the opinion of who is writing here is that this is no good, neither for neighboring social sciences, nor for economics itself. Defining preferences only as rankings of given alternatives may be criticized out of rationality criteria. Even though preference orderings over alternatives can be judged to be more or less ('thinly') rational in terms of formal properties (transitivity, completeness etc); there is a super-ordinate question of whether it is ('broadly') rational to define preferences as rank orders to start with. And the answer is that it is often inefficient to do so, in the precise economic sense that it is likely to entail losses. Negotiation research has been especially instructive in showing that being unable to distinguish between preference over 'positions', i.e. specific actions and targets, and the 'interests' they are supposed to serve, is an ineffective way of defining preferences, as advantageous deals are lost in this way (Raiffa 1982; Bazerman and Carroll 1987). This prescription is entirely consistent with a discovery oriented approach to decision making. In fact, preferences over alternatives or 'positions' – a party prefers a price of x, or a y% of shares or chairs in a venture over other alternatives - can and should be seen just as hypotheses on types and amounts of resources that may contribute to realize a set of underlying interests. Not only to generate other matters which have a bearing for those interests (a case in discovering new alternatives); but also, and vice versa, to enlarge the set of interests which might be realized through the generated alternatives increases simultaneously the likelihood and quality of agreements. In other terms, utility judgments too could be modeled as sets of parameters U', U'', U''' for ranking options, not necessarily commensurable and comparable even if held by the same person, whereas larger sets are superior to narrower sets.

In sum, it may be said that multi-criteria and hierarchically structured preferences are defined more rationally than narrowly defined (single criterion) and flat (actions ranking only) preferences: preferences should not be defined 'over alternatives', but be defined as semi-independent sets of values and interests, allowing different operationalizations into orders of alternatives. This rule is consistent with empirical research on the cognitive structure of human motivation, as composed by layers of general needs and values, and more 'operationalized' and testable judgments about what matters or things, at different levels or amounts, have positive or negative effects on those values (Locke 1991). The rule is also consistent with a freedom criterion: wider sets of interests widen the set of relevant real options that might be perceived, thereby reducing the likelihood of unnecessary (sub-optimal, not intendedly rational) adaptation to 'option poor' conditions (Sen 2002). Finally, this rule of rational preference definition is consistent with the rule of rational discovery of alternatives outlined above: a shift of the matter of choice from the prediction and evaluation of specific, identified, describable actions and consequences, in correspondence of foreseeable states of the world; to the anticipation and ranking of the *potential* for generating streams of undescribable, unspecified actions and consequences into which a move can be operationalized, no matter what the state of the world. [11]

Table 1 summarizes the differences between the 'highly powered heuristics' of the 'epistemic model of rational choice' and the 'low powered heuristics' of the 'behavioral model of rational choice'. Roughly, the epistemic model imply a prescription of *not* following most of the biasing heuristics guiding ‘normal’ (and most often inferior) behavior highlighted by descriptive behavioral decision making research; but it indicates how to search rationally rather than just resorting to deductive optimal choice.

The comparison should also clarify that the way of connecting economic and behavioral models of decision making proposed here differs from that of integrating into rational choice models ‘parameters’ that represent ‘normal’ behaviors .

Finally, the formalization of utility functions helps in seeing that ‘utility maximizing’ rules are a particular case - in which knowledge acquisition and development is not considered - of what we have called an epistemic model of rational choice. In fact, most economic models consider structured problems that can be written as Max $U\, p_i\, (a_i, s_j)$, or eventually Max U $p_i\, (a_i, s_j) – Cij$, where Cij is the cost of search for information on alternatives a_i and states of the world s_j. They do not include terms that represent research. Rather than enlarging this standard utility function with parameters reflecting just what people frequently do in searching, we have proposed to enrich the utility function with terms reflecting rational research procedures (that can be and are applied in the best research processes we know about). Utility maximizing models with Bayesian learning, are still a particular case of the general epistemic model formulated here, their generic form being Max $u_k/S= SUM_{k,h,i,,m,l}\; u_k\, p\, (\, U_k\, ,F_h, A_i\, I_m\, H_l\, /S)$. In other words, Bayesian models deal with problems in which it is known what the relevant actions, outcomes, utility parameters, and state of the world parameters are, and where the probability that hypotheses on decision inputs are true can be assessed (and up-dated). Hence the above equation expresses the expected utility of any solution, given the probability that particular actions are taken, that particular outcomes occurred, that accepted information and hypotheses are true (March 1976). [12]

Table 1

About here

PREDICTIONS: A COGNITIVE FOUNDATION FOR INNOVATION-ORIENTED ORGANIZATION

Some important empirical regularities can be better explained by the hypothesis that decision makers engage in rational discovery than by the hypotheses that they are guided either by deductive economic choice or by heuristic behavioral choice.
The following implications and applications of the notion of epistemic rationality show how testable propositions about economic behaviors can be derived by the model of decision making outlined above.

- *Strategy formulation*. Problem boundaries, i.e. the sets of *a*, *s*, *f* entering problem models, expand with experience in unstructured decision areas, where discovery is relevant. This phenomenon has been documented by various studies on organizational decision making. For example, investment decisions on information systems have resulted in being framed as technological choices with rather unknown consequences at early stages of collective and focal firm experience in the area; while the problem model expanded to include economic and organizational parameters in more mature stages (Grandori 1984). Problem model expansion has also been detected in strategic decision making, whereas initial trial and error positioning is replaced by a model of the major competitive forces to be taken into account in the focal firm strategic analysis (Gavetti and Rifkin 2004). In public decision making, it has been documented that educational and other public programs, initially set up for generating instruction level and job opportunity results, have then been discovered to cause a variety of other consequences (social integration, mobility); which are incorporated into the problem model guiding subsequent decisions (Chen and Rossi 1981).

The set of utility parameters or 'preferences' used in economic decision making in a certain domain also, typically, exhibit expansion dynamics. 'HR' evaluation practices provide a good example of how evaluation criteria of 'human alternatives' has evolved over years from a task-centered and single productivity approach to multiple criteria and 'balanced scorecards' approaches (job, skills, potential, behavioral and output performance etc).

In addition to this descriptive and predictive value, models of epistemic rationality can provide a needed and missing prescriptive foundation for strategy formulation. In fact, it seems clear that in the kind of unstructured problem solving that strategy making is all about, deductive value maximizing falls short of addressing the generation of alternatives, while satisficing and other behavioral heuristics fall short of guiding challenging, innovative, thoughtful, breakthrough discovery of alternatives. And even in the presence of strategic interaction (which indeed complicates things), the idea that players make moves so as to provide corroborating or falsifying information in order to shape other players' conjectures, seems however worthwhile exploring, as a next, game-like, development of epistemic rationality theory. The model presented here formalizes and give precise cognitive foundations to the general prescription for ‘wide search’ that is present in strategic decision making (Nutt 2004).

- *Investments in research.* Decision processes starting in comparable initial states of knowledge, attain superior results if a wider series of sets of A, S and F, and a wider set of ‘objectives’ or utility parameters are generated than a narrower series of sets. Empirical research on organizational decision processes, considering a variety of classes of decision areas – from HR to technology, from marketing to R&D - has consistently shown this positive effect of investment in research on possible alternatives and their consequences on performance parameters (Hickson et al. 1996; Witte and Zimmerman 1986). Actually, the sheer existence of huge investments in R&D would follow naturally from the premise that (effective) firms (operating in innovative areas) do engage in systematic research and rational discovery, whereas this ‘effort’ is by no means a search cost to be reduced but an investment in research to be expanded in order to generate options. Furthermore, they do so even when the expected payoff of research projects cannot be calculated, let alone the content of projects described ex-ante, so that their behavior is not well explained by deductive economic rational choice either.

- *Un-decomposable organization structures.* When economic activities involve complex knowledge exchange, sharing and growth, organization structures are nearly-un-decomposable, rather than nearly-decomposable systems. Simon’s notion of near-decomposability (1969) derives from that of bounded rationality and computational complexity : organizations are supposed to be a means for reducing complexity into limited sub-problems, thereby providing ‘decision premises’ and pre-defined problem models. Organization structures are supposed to structure problems in a relatively stable and programmed way (March and Simon 1958). However, if there are at least two types of information complexity, as we have argued, not just computational complexity (an issue of information cost or effort), but also epistemic complexity (an issue of knowledge validity), then organizations should exist that allow ‘problem shifting’ (or redefinition) rather than problem decomposition. These organizations should not look like either hierarchies or markets, as both these forms of organizing do decompose problems into local quasi-disconnected components (they are ‘modular’ in modern parlance): they differ only in the mechanisms of (weak) connection that they employ, such as roles specialized in coordination versus prices. Rather, where it is important to discover new actions and projects, and it is difficult to construct problem models (i.e. complex knowledge is involved), then we should observe and do observe organization forms that allow problem models to expand and change. A variety of those organization forms, all characterized by providing ‘flexibility’ in problem re-definition and competence re-combinations, have in fact been identified as appropriate in innovative, complex knowledge, unstable settings (Lewin and Volberda 1999). As those authors pointed out, theoretical explanations of why those forms are appropriate are rather underdeveloped, and the model of decision making and problem solving as rational discovery proposed here provides a possible cognitive, micro-analytic foundation.

- *Exploration.* It has been influentially observed that ‘exploration’ , rather than just ‘exploitation’, does occur and is an essential part of organizational decision making and learning (March 1991), whereas the first includes things such as ‘search, variation, experimentation, flexibility and discovery’ and the second includes things such as ‘choice, selection, production, efficiency and implementation’. March’s article, and most subsequent research based on it, then develops consequences of that distinction especially in terms of a trade-off: how much effort is worthwhile investing in research-variation-discovery processes, and how much in choice-selection-implementation. The notion of epistemic rationality develops rather what the cognitive processes distinctively guiding exploration might be (and should be) and why exploration occurs at all. Some exploration would certainly also occur through local search (Gavetti and Levinthal 2000), blind variation and selection (Campbell 1960), and routine shift (Zollo and Winter 2002). But these processes, all rooted in the bounded rationality tradition, are slower and more error prone than those actually observed, reach innovative outcomes less frequently than is actually observed and under-exploit the even average cognitive capacity of man, let alone the superior. In addition, the downsides, the risks and the ‘vulnerability’ of exploration (going far without knowing where) (March 1991), can be substantially reduced by adopting ‘high powered discovery heuristics’ of the type described here (modeling problems, developing causal explanations, going far with hypotheses), rather than the ‘low powered search heuristics’ of the bounded rationality repertory (repeating successful actions). Research sustaining this argument exists on technological innovation. For example, Fleming and Sorenson (2004) show that the contribution provided by science is important in technological innovation when the context of search is rugged, i.e.

when it is not regular and well structured, while relatively blind and local search procedures work approximately as well as more causal and hypotheses testing ones in non rugged landscapes where the adjacent points of the terrain do not differ dramatically in their usefulness. My argument takes a further step with respect to the notion of the 'use of science' on unstructured, difficult problem and asks: is 'science ' a thing out there reserved to scientists, or can problem solvers and decision maker proceed themselves as scientists? Are scientists the only ‘men’ entitled to less bounded or un-bounded rationality? As Kelly (1963:5) very aptly put it, criticizing the attitude of traditional psychology (but the observation can be extended to the behavioral tradition, that, in fact, has roots in psychology): “ I, being a psychologist and therefore a scientist am performing this experiment in order to improve the prediction and control of certain human phenomena; but my subject, being merely a human organism, is obviously propelled by inexorable drives welling up within him, or else he is in gluttonous pursuit of sustenance and shelter” .

Similarly, simulation studies by Gavetti and Levinthal (2000) have shown that substituting local and experiential search rules for semi-intelligent vicarious learning, allowing ‘cognitive representations’ of problems to shift and diffuse through imitation, would lead to improvements in performance. My proposal in this paper is to take a further step and allow fully intelligent shifts of representation (which in addition, has the merit of explaining where the first mover shifts in representations, the ‘comparable experience’ worth being imitated, comes from). As Bandura (1986) has argued, beyond learning by direct experience, and learning by vicarious experience, a third possibility, superior whenever feasible, is learning by ‘modeling’, i.e. by constructing causal models or at least general empirical laws about the behaviors which are likely to lead to superior performance.[13] This step has been blocked by the idea that this would equate to assuming 'omniscience'; but we argued here that this is not the case, there can be fully intelligent problem modeling without omniscience.

- *Epistemic communities***.** The governance of knowledge exchange, sharing and growth has become an increasingly important issue in economic and management life as well as research (Kogut and Zander 1992; Davenport and Prusak 1998). It can be argued that, however, the interpretative frames are, once again, on the limits of knowledge rather than on its strengths, on its stickiness, untransferability, contextuality, rather than on its generality, potential for intercultural and universal dialogue and abstraction; in fact, the models employed are drawn more from the psychology and sociology of knowledge than from logic and philosophy of knowledge (Grandori and Kogut 2002).

Similarly, the study of communities as a chief mode of knowledge governance has considered mostly a routinized, practice-driven, context-specific mode (Brown, Dusguid 1998). Only recently, with some difficulty, the obvious alternative (aren't scientific communities a very available example?) has emerged: that of 'epistemic communities' (Haas 1992). The difference between communities of practice and epistemic communities, however, is difficult to capture without seeing the difference in the models of rationality driving them. It has been talked of shared methods, of shared knowledge, of common values and motives, but these apply to all sort of communities. The difference between bounded and epistemic rationality can highlight and explain the different structures and behaviors between routine-driven, action specific and context specific, practice-based communities; versus critical, hypothesis testing, theory – driven and generalization-oriented communities. Among the salient organizational differences, there are important traits of decision and control mechanisms: critical and innovative hypotheses testing needs variety rather than homogeneity of inputs (Ashby 1952); admission of errors as experiments rather than the punishment of them (Popper 1989); evaluation on competences and decision making procedures rather than obsession with successful outcomes, where they are poorly measurable and subject to high exogenous variance (Ouchi 1979; Starbuck 2004).

- *Design***.** Design as a 'generative', creative exercise of fundamental importance in management is also a theme in the course of revitalization (Boland and Collopy, 2004). As these last authors notice: 'The design attitude appreciates that the cost of not conceiving of a better course of action than those that are already been considered is often much higher than making the wrong choice among them'. The problem with these interesting insights and interest in revitalizing a design logic, is that it is inconsistent with the idea of bounded rationality, at least if intended precisely as the heuristic of weighting the costs of search more than the opportunity costs. This contradiction usually goes unnoticed. In fact the classic work, typically used as a foundation to design, Simon's *Sciences of the artificial* , is actually a double edged sword. As stated in the preface to the third edition (Simon 1996: xii) : "Engineering, medicine, business, architecture and painting are concerned not with the necessary but with the contingent - not with how things are but with how they might be - in short with design" . However, only very limited search for those better worlds would be undertaken by 'satisficing' actors.[14]

CONCLUDING REMARKS: FROM A BEHAVIORAL TO AN EPISTEMIC THEORY OF THE FIRM

We have argued that the equation between fully intelligent, rational problem modeling and maximizing decision rules with 'omniscience' is logically and philosophically untenable. The bounded rationality 'assumption', interpreted in this way, has become a block to the development of our understanding of decision making, and for the development of a dialogue and cross fertilization between economic and behavioral sciences. In this paper the possible features of an epistemic, rather than 'bounded', model of rationality have been explored. It would direct our attention toward capturing and studying decision making at the best level of human cognitive capabilities, rather than at the average or even lower bound levels. It would enable to be prescriptive on how to improve problem modeling and solving, how to be rational in discovery, without merely resorting to the deductive model of rational choice. It reconnects the behavioral and the economic theory of rationality, by disentangling the latter from an 'omni-science' assumption, and disentangling the former from a 'no-science' assumption.

In this paper the focus has been on how economic actors may behave out of epistemic rationality, and how widely observed behaviors and structures are actually difficult to explain without admitting rational discovery processes, such as large R&D investments, exploration, problem expansion; and economic governance by epistemic communities and nearly-un-decomposable organization structures. The application of epistemic rationality at the level of a firm actor may contribute in extending the 'behavioral theory of the firm' into what may called 'an epistemic theory of the firm' - in the March and

Cyert's sense of a theory of how firms behave. However, further implications of the points made here on abandoning the divide between bounded and unbounded rationality as it has become institutionalized, and reconnecting rational choice and rational discovery could be developed in the direction of explaining the very existence of firms, i.e. of the theory of the firm proper. But this is another chapter of the story (Grandori 2005).

NOTES

[1] It should be noticed that the notion of 'broad' rationality, as contrasted to a 'thin' one as used here, is close to the original meaning of the distinction in Elster (1985) and quite different from that proposed by Foss (2001) , in which 'thick *bounded* rationality' is equated to the cognitive heuristics and biases side of it. In my view, the 'behavioral decision theory' tradition still conveys a thin view of bounded rationality, as far as it is based on sacrifices in accuracy for savings in cognitive effort, and on the study of (second best) 'deviations' from the template of rational choice. Actually this is precisely the version in which bounded rationality is becoming widely used in economics (e.g. Thaler 1991), rather than remaining just a mere 'rhetorical device' (Foss 2003).

[2] To be fair, there is an unresolved ambiguity in Simon's writings about whether value maximizing and the rational choice model is to be rejected as empirically false; or, as in his early writings he seemed to mean, value maximizing is possible but under 'restrictive conditions' – i.e. structured problems. While most organization theory and research has subscribed to the first version, I have always argued, and still imply here, that only the second version is acceptable (Grandori 1984).

[3] For the sake of etymological precision, 'economic' comes from 'oikos' (house) and 'nomia' (regulation, governance) – the governance of household, the principle of 'good administration', wisely saving and allocating resources.

[4] A fascinating criticism of mathematics, for having hidden its heuristic component, and having focused only on its deductive component, that would apply on the current way in which economics is using, or has become a branch of, mathematics, see Lakatos (1970).

[5] This description of the elements extends and revises Simon's (1955) list of elements entering any model of rational decision making. The idea that economic problem solving can be modeled in large part as scientific discovery, hence as hypotheses testing under epistemic uncertainty, is the complementary reverse of modeling scientific discovery as 'human problem solving', in the sense of searching in a decision tree under computational complexity, that was the approach followed by Simon (Simon, Langley, Bradshaw 1981)

[6] Most resources, and typically human and technical resources, can generate wide and not boundable streams of possible services or activities (Penrose 1959)

[7] When I wrote this corollary, I noticed that it gives an explanation (why it is rational to do so) of the observational proposition (advanced by Shackle, 1979) that choice under strong uncertainty occurs among 'options', 'enterprises' and 'policies' rather than specific and precise actions.

[8] The term 'small world' is used by Savage to indicate a stylized, reduced problem model, as contrasted with the real, unbounded 'grand world'; it has nothing to do with the notion of 'small world' used in network research.

[9] I am going to explore exclusively the first road, consistently with my general definition of rationality as an entirely procedural affair It is not only a matter of self-consistency, though. In that respect, I share most economists' and many social scientists' diffidence towards any substantive preference assessment. Actually, even Elster and Sen, after having declared to be addressing substantive rationality, actually provide procedural and content-free criteria. Elster's criteria that preference should be 'consciously' and 'autonomously' defined is more procedural rather than substantive (beyond not being really clear, as the author himself acknowledges). Similarly, Sen's notion of interest as freedom to achieve well-being, as the variety of real opportunities open to an actor (Sen 1999) is also in the end avoiding any judgment on whether some objectives are better than others in a substantive way (i.e. whether pursuing the 'well'-being or the 'evil' of others or of the self; whether material or immaterial resource acquisitions; etc.).

[10] The results of an empirical survey on Italian FIAT blue collar workers satisfaction (Accornero 1980) went as follow: unexpectedly they declared high satisfaction on all aspects of their working life; but when asked whether they would have liked to see their sons doing the same job, they responded: never. Hence, a 'theory of preference' which just says that they are formed on the basis of experience is not even fully accurate as a descriptive theory, in addition to being dangerous in prescriptive terms.

[11] This type of choice may resemble that among 'real options' – in fact an approach developed in finance for uncertain conditions and imported into business strategy theorizing (Adler, Levinthal 2004) . As those authors notice, though, real option theory still implies knowledge and descriptions of the options that can be 'acquired' and exercised, and a 'wait and see' mode of acquiring information. In other words, what we have come up with in this paper seems to take a further step in envisaging options with unknown skeins of actions attached, and the possibility of actively designing them.

[12] In other words, the models of 'rational search' based on Bayesian inference (Radner 2000; Oaksford and Chater 1998) focus on a particular, relatively structured, case of discovery. As a consequence, we can do better than choosing between the often contrasted 'Bayesian' and 'Popperian' approaches as a matter of faith or assumption on whether probability judgments on the likelihood of an hypothesis being true can or cannot be made in general. Consistently with our idea that the rationality of decision strategies depends on the structure of problems that are defined, a more rationally posed question is whether we can structure the matter at hand enough for having conventionally finite possibilities and making probability judgments, or not. Hence , me may well be sometimes Bayesian and sometimes Popperian. Even in science , this is the case: there are structured problems – say a phenomenon that may be represented by some specified alternative mathematical functions, among which we may select 'the best' with maximum likelihood methods – while in less structured problems we have rival theories that may live for years in a state of 'acceptance' and 'corroboration' without any possibility to compare their relative likelihood.

[13] Bandura called this type of learning 'role modeling' as he was chiefly applying his discussion to the learning of individual organizational behaviors. But the argument can be generalized to any behavior.

[14] There are exceptions to the plain use of the 'Sciences of the artificial', computational complexity version of design theory, which point in the same direction as the argument and model developed here: for example Hatchuel (2001) notices that Simon's view of design is an 'unfinished program' and would require an extension based on 'expandable' forms of rationality; and Liedtka (2000) notices that the logic of strategy making as design resembles that of hypotheses testing.

References

Accornero A., 1980 'Le idee dell'operaio FIAT sul lavoro, sindacato, politica' *Rinascita*, n. 8.

Adner R., Levinthal D.A. 2004 'What is *not* a real option: considering boundaries for the application of real options to business strategy' *Academy of Management Review* 29/1:74-85

Akerlof G.A., Kranton R.E., 2000 Economics and identity. *Quarterly Journal of Economics* CXV:715- 753

Arrow K.J., 2004 'Is bounded rationality unboundedly rational? Some ruminations' In M. Augier, J.G. March (eds.) *Models of a man. Essays in memory of Herbert A. Simon.* Cambridge:MIT Press.

Ashby W.R., 1952 *Design for a brain*. London: Chapman and Hall.

Bandura A., 1986 *Social foundations of thought and action.* Englewood Cliffs: Prentice-Hall.

Baumol W.J, 2004 'On rational satisficing' In M. Augier, J.G. March (eds.) *Models of a man. Essays in memory of Herbert A. Simon.* Cambridge:MIT Press.

Baumol W.J., Quandt R.E., 1964 'Rules of thumb and optimally imperfect decisions", *American Economic Review*, 54. 23-46.

Bazerman M.H., Carroll J.S., 1987 'Negotiator Cognition' In L.L. Cummings, B.M. Staw (eds) *Resarch in Organizational Behavior,* 9. Greenwich CT: Jay Press.

Boland R.J., Collopy F., 2004 *Managing as designing* Stanford: Stanford University Press

Bown J.S., Dusguid P., 1991 'Organizational learning and Communities-of-practice: Towards a unified view of working, learning and innovation' *Organization Science* 2/1:40-57

Campbell D.T., 1960 'Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes' *Psychological Review*, n. 67, 380-400.

Chen H.T., Rossi P.H., 1981 'A multi-goal theory-driven approach to evaluation'. *Evaluation Research,* 6: 38-54.

Cohen M.D. et al 1996 ‘Routines and other recurring patterns of organizations: contemporary research issues’ *Industrial and Corporate Change* 5/3:653-98

Cowan R., David P., Foray D. 2000, ‘The Explicit Economics of Knowledge Codification and Tacitness’ Industrial *and Corporate Change* 9/2:212-53.

Cyert R.M. e March J.J., 1963 *A behavioral theory of the firm,* New York: Prentice-Hall.

Davenport T.H., L. Prusak, 1998 W*orking knowledge: How organizations manage what they know*. Cambridge: Harvard University Press.

Demsetz H., 1991 ‘The theory of the firm revisited’. In O.Williamson, S.Winter (eds.) *The nature of the firm: Origins, evolution and development.*_Oxford: Oxford University Press: 159-178.

Elster J., 1983 *Sour grapes. Studies in the subversion of rationality*. Cambridge: Cambridge University Press.

Einhorn H.J., Hogart R.M, 1978 ‘Confidence in judgment: on the illusion of validity’ *Psychological Review* 85:395-416.

Fleming L., Sorenson O., 2004 ‘Science as map in technology search’ *Strategic Management Journal* 25: 909-928.

Foss N., 2001 ‘Bounded rationality in the economics of organization: present use and some future possibilities’ *Journal of Management and Governance* 5/3-4: 401-425.

Foss N. 2003 ‘“The Rhetorical Dimensions of Bounded Rationality: Herbert A. Simon and Organizational Economics,” in Salvatore Rizzello, ed. *Cognitive Paradigms in Economics*. London: Routledge, 2003

Gavetti G., Levinthal D., 2000 ‘Looking forward and looking backward: cognitive and experiential search’ A*dministrative Science Quarterly* 45:113-137.

Gavetti G., Rifkin J.W., 2004 ‘On the origin of strategy: Action and cognition over time’. HBS paper.

Gigerenzer G., Selten R., 2001 ‘Rethinking rationality’ In G. Gigerenzer, R. Selten (eds) *Bounded rationality: The adaptive toolbox.* Cambridge: The MIT Press.

Godel K., 1931 ‘Uber Formal Unentsheidbare der Principia Mathematica und Verwandter Systeme,I’ *Monatshefte fur Mathematik und Physik* 38:173-198.

Grandori A., 1984 ‘A prescriptive contingency view of organizational decision making", *Administrative Science Quarterly*, 29: 192-208.

Grandori A., 2001 ‘Methodological options for an integrated perspective on organization’ *Human Relation. Millennium Special Issue*, 54/1:37-47

Grandori A., 2005 ‘Firm-like contracts: from task contingencies to resource commitments’. Sabbatical year positional paper. www.crorabocconi.it (Papers).

Grandori A., Kogut B., 2002 ‘Dialogue on Knowledge and organization’ *Organization Science* 13/3:224-231

Haas P., 1992 ‘Introduction: Epistemic communities and international policy coordination’ *International Organization* 46/1.

Hanson N.R., 1958 *Patterns of discovery. An enquiry into the conceptual foundation of science.* CUP

Hatchuel, 2002 ‘Towards design theory and expandable rationality: The unfinished programme of Herbert Simon’ *Journal of Management and Governance* 5/3-4:260-273

Hayek von F., 1945 ‘The Use of Knowledge in Society’, *American Economic Review*, 35:519-530, September.

Hickson David, Butler R.J, Mallory G.R., Wilson D.C., 1986 *Top Decision*, Oxford: Blackwell.

Kahneman D., Slovic P., Tversky A. (eds.), 1982 *Judgment under uncertainty: Heuristics and biases*, Cambridge University Press.

Kelly G.A., 1963 *A theory of personality* . New York: Norton.

Klayman J., Ha Y.-W., 1986 ‘Confirmation, disconfirmation and information in hypothesis testing’ *Psychological Review* 94/2: 211-228.

Knight F.H., 1921 *Risk, uncertainty and profit.* Boston: Houghton Mifflin.

Kogut B., Zander U., 1992 ‘Knowledge of the Firm, Combinative capabilities, and the replication of technology’ *Organization Science*, Vol. 3, No. 3, August, pp.383-397.

Lakatos I., 1970 ‘Falsification and the Methodology of Scientific Research Programmes’ in I.Lakatos and A.Musgrave (a cura di), *Criticism and the Growth of Knowledge*, Cambridge, Cambridge University Press

----- ,1976 *Proofs and Refutations. The Logic of Mathematical Discovery* (edited by J.Worral and G.Currie). Cambridge University Press, Cambridge

Lewin A.Y, Volberda H.W., 1999 'Prolegomena on co-evolution: A framework for research on strategy and new organization forms' *Organization Science* 10/5:519-534.

Lichtenstein S., Fishoff B., Phillips L.D., 1982 'Calibration of probabilities' in Kahneman D., Slovic P., Tversky A. (eds.) *Judgment under uncertainty: Heuristics and biases*, Cambridge University Press.

Liedtka J., 2000 'In defense of strategy as design' California Management Review 42/3:8-30.

Lindblom C.E., 1959 "The Science of 'Muddling Through'", *Public Administration Review*, 19:78-88.

Loasby B., 2004 'Economics after Simon' In M. Augier, J.G. March (eds.) *Models of a man. Essays in memory of Herbert A. Simon.* Cambridge:MIT Press.

Locke E.A.,1991'The motivation sequence, the motivation hub, and the motivation core'. *Organizational Behavior and Human Decision Processes,* 50: 288-299.

March J.G., 1994 *A primer on decision making*. New York: Free Press.

March J.G, Simon H.A.,1958 *Organizations,* New York: Wiley

March L. 1976 'The logic of design and the question of value'. In L. March (ed) *The architecture of form.* Cambridge: Cambridge University Press.

Nelson R.R., Winter S.G., 1982 *An Evolutionary Theory of Economic Change*. Harvard University Press.

Nutt P.C., 2004 'Expanding the search for alternatives during strategic decision-making' *Academy of Managenet Executive* 18/4: 13-28.

Ouchi W.G., 1979 'A conceptual framework for design of organizational control mechanism' *Management Science* 25:833-848

Penrose E., 1959 *The theory of the growth of the firm.* Oxford: Oxford University Press.

Popper K.R. 1935 *Der Logik der Forschung*, Vienna (*The Logic of Scientific Discovery*, London, Hutchinson, 1959).

------ 1989 'The critical approach versus the mystique of leadership', *Human Systems Management*, vol. 8, pp. 259-265

Radner R., 2000 'Costly and bounded rationality in individual and team decision making'. *Industrial and Corporate Change* 9/4:623-658

Rabin M., 2002 'A perspective on psychology and economics' *European Economic Review* 46:657-685

Raiffa H., 1982 *The Art and Science of Negotiation*, Cambridge University Press, Cambridge.

Russell B., 1948 *Human Knowledge: Its scope and limits.* New York: Simon &Schuster.

Sen A., 1999 *Commodities and capabilities.* Oxford: Oxford University Press.
------ 2002 *Rationality and freedom*. Cambridge: Harvard University Press.

Shackle G.L. 1972 *Epistemics and economics*. Cambridge: Cambridge University Press.
------ 1979 *Imagination and the nature of choice.* Edinburgh: Edinburgh University press.

Simon H.A., 1947 *Administrative Behavior*, New York, Macmillan.
------ 1955 'A Behavioral Model of Rational Choice', *Quarterly Journal of Economics,* vol. 69, pp. 99-118.
------ 1976 'From substantive to procedural rationality', in S.J.Latsis (a cura di), *Method and Appraisal in Economics,* Cambridge, Cambridge University Press.
------ 1977 *Models of discovery and other topics in the method of science,* Reidel, Dordrecht, Boston.
------ 1979 'Rational decision making in business organizations'. *American Economic Review,* vol. 69, 493-513 (Nobel lecture).
------ 1996 *The Sciences of the Artificial.* 3rd edition. Cambridge, MA:MIT Press

Simon H.A., Langley P.W., Bradshaw G.L.,1981 'Scientific discovery as problem solving'. *Synthése* 47: 1-27

Starbuck W., 2004 'Methodological Challenges Posed by Measures of Performance' *Journal of Management and Governance* 8/4: 337 - 343

Thaler R.H., 1991 *Quasi rational economics* New York : Russell Sage Foundation

Tirole J., 1999 'Incomplete contracts: where do we stand?' *Econometric* 67/4:741-781.

Weick K., 1979 'Cognitive processes in organizations' in B. Shaw (ed) *Research in Organizational Behavior.* Greenwich, JAI Press.

Witte E. e Zimmermann H.J., 1986 *Empirical research on Organization decision-making*, Amsterdam: North Holland.

Young R.M., 1998 'Rational analysis of exploratory choice' in M. Oaksford, N.Chater (eds) *Rational models of cognition*. Oxford University Press.

Zollo M., Winter S., 2002 'Deliberate learning and the evolution of dynamic capabilities' *Organization Science* 13/3:339-351.

Table 1. A comparison between bounded rationality and epistemic rationality

Bounded rationality heuristics	***Epistemic rationality heuristics***
Look for and accept any a_i for which $U [f_i (a_i) . p_i] > U [f_{l} (a_l). p_l]$	Generate information I_m and hypotheses H_l on alternative A_x, F_y, $S_{j,,}$ U_k , so as to Pareto -improve $Y (p_k U_k, p_y F_y, p_x A_x, p_j S_{j\,,} p_l H_{l,} , p_m I_{m,,} p_{ih} C_{ih\,,})$
	Do not assign probabilities in unbounded, unrepeated problems (i.e. where there is no logical or empirical basis for probability judgments)
Raise /lower aspiration levels as a function of 'favorable' vs 'unfavorable' experiments (frequency of finding)	Revise possibility judgments, not desirability judgments on the basis of observed frequencies
	Formulate wide and hierarchical set of preferences rather than narrower and alternative-driven sets
Test problem model through direct and vicarious experience.	Test problem models through controlled experimentation and law corroboration
On – line experimentation	Off – line experimentation