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Natural Agents, Complex Systems and Uncertain Environments: Results from Simulations on Heuristic Organizations

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By Lorenzo Corno

ABSTRACT

The primary objective of this work is to propose a naturalistic perspective on human cognition and agency as a foundation for the investigation and representation of microeconomic phenomena arising from the interactive behavior of organizations and of agents within organizations. This dissertation examines the evolution of bounded rationality in its ecological interpretation and explores both theoretically and practically the possibility of empirically grounding the dynamics of economics as an evolving complex system, starting from a realistic and descriptive attempt to approach the representation and modeling of economic agents.

The thesis traces the development of Herbert Simon's concept of *bounded rationality* from its origins, focusing on the Adaptive Behavior and Cognition legacy that recognized the fundamental relationship between cognition and the agent's environment and interpreted rationality from an adaptive perspective. From the idealized *homo economicus,* highlighting the relevance of uncertainty, this theoretical journey trace the shift to a more realistic anthropology of *homo heuristicus,* by identifying the heuristics adopted in decision-making process – encompassed within an embodied and enactive dimension of cognition – as building blocks for a mind-society microfoundation trajectory.

Subsequently, complex social systems are presented as the fundamental units of economic reality, alongside a perspective from which to pursue microfoundation attempts starting from the representation of real-world agents. The epistemological and methodological coordinates oriented towards emergence and interactions, preparatory to the endeavor to merge Simon's analysis on cognition and that on organizations as hierarchical near-decomposable complex systems, are then outlined.

A suitable paradigm that indicates which phenomena need to be explained and microfounded is then identified: a theoretical framework that combines evolutionary and complexity economics and conceptualizes the economy as an evolving complex system, denying the concept of equilibrium and focusing on dynamics, heterogeneity, and epistemological emergence. Within this paradigm,

homo heuristicus finds its habitat in organizations, determining their resulting problem-solving behavior in uncertain environments.

The second part of the thesis attempts to practically follow the traced theoretical route by incorporating the anthropology of homo heuristicus into Agent-based simulations. These are programmed on analytical tractable models that aim to provide a basis – consisting in the logic adopted and the result obtained – for implementing more sophisticated models such as Agent-Based or NK models. In this phase, populations of performing heuristic agents (organizations) in a turbulent environment are simulated, starting from the most fundamental heuristic: *satisficing*. Relative and absolute aspiration levels are set and turbulence is generated, and various results concerning observable properties and dynamics at the aggregate level are observed, analyzed, and interpreted. The behaviors of agents are progressively sophisticated and enriched by incorporating local search behavior, exploitation-driven organizational learning, exploration and exploitation strategies, social imitation heuristics and and other secondary more realistic decision-making and problem solving traits, thus providing theoretical contributions and identifying practical orientations.

1 NATURAL AGENTS

1.1 Olympian Rationality in Economic Tradition

The perfect rationality assumed by models of economic man imagines a hypothetical agent – the well known *homo economicus* – who has complete information about the options available for choice, perfect foresight of the consequences from selecting among those alternatives, and the capacity to solve a complex optimization problem that identifies the option which maximizes the agent's personal utility (Wheeler, 2018). Misinterpreting the impulse for knowledge of reality associated by Aristotle with the rationality of the "human animal", this last distinguishing characteristic of the human being has been increasingly conceptualized by the economic tradition with an impeccable "Laplacian" ability to foresee and know every detail of present and future contingencies of the universe in order to suit one's own interests, thus transforming *zòon lògon èchon* into a divine *zòon oikonomikòn*.

As explained by Wheeler (2018) the metamorphosis of the concept of the "economic man" has been remarkable over the years. Initially presented by John Stuart Mill in 1844, this theoretical figure was characterized by self-interest and a focus on maximizing personal utility. This notion was further developed by Jevons in 1871 with a mathematical approach to marginal utility, which brought greater precision to the representation of the economic agent. The evolution continued into the 20th century, with Frank Knight adding layers to Jevons' computing individual in 1921 by assigning attributes of perfect foresight and specific risks, similar to those of a "slot machine". This progression culminated in the modern definition of the rational economic agent, articulated by Paul Samuelson in 1947 through the revealed preferences approach. Complementing this transformation, the seminal work of Von Neumann and Morgenstern in 1944 shifted economic analysis from a focus on the contemplative aspects of decision-making to an emphasis on the dynamics of the choice processes themselves.

Contemporary economic theory originates from the insight that human beings prefer some outcomes over others, even when these outcomes are only considered hypothetically. A fully rational individual, as defined by the prevailing model of synchronous decision-making under risk, is one whose relative evaluations of various outcomes adhere to the principle of expected utility maximization. The principle of expected utility theory presupposes indeed a structure where preferences conform to certain axioms, allowing their expression as inequalities of mathematical expectations that rank comparative elements from least to most desirable. Assuming that these beliefs maintain an internal consistency, it is believed that the optimal strategies can be executed. In line with this "Olympian" model of rationality (Simon, 1983), the economic individual is considered capable of representing, evaluating and comparing all potential choices within the available options and selecting the most advantageous alternative. (Benincasa, 2020).

After a decline in interest during the late nineteenth and early twentieth centuries, the concept of rationality in economics witnessed, in its final form, a resurrection during the 1950s and 1960s as a theoretical attempt of addressing the discrepancy between the description of an uncertain world and the normativity required of any theory of reasonableness, continuing in the wake of solutions formulated after the emergence of probability in Western thought. This was achieved by refining the traditional solution of manipulating the utility or probability function while maintaining the ideal of maximization or optimization, as well as specifying that the decision maker relies on subjective probability to estimate the desired outcome and to calculate the subjective expected utility of an economic opportunity. This formulation, promoted and axiomatised by L. J. Savage in 1954 in the wake of earlier work by Ramsey and von Neumann, combines two subjective concepts: firstly, a personal utility function and, secondly, a personal probability distribution, usually based and updated on Bayesian probability theory.

Contemporary with the portrait of economic agents as fully rational Bayesian maximizers of subjective utility, the study of mathematical models of strategic interactions between rational agents led to the development of subsequent various applications in economics and management. Among these, in the field of strategic studies and policy making, the game theory tradition starts from the assumption that perfectly rational individuals act to secure the optimal payoff in pursuing a strategy, aimed at modelling the dynamics of cooperation and conflict between competing entities. Amidst this proliferation of declinations and applications based on rationality, Simon's conceptualisation of bounded rationality was a crucial event that prompted scholars to thoroughly re-evaluate human reasoning, which led to an overall redefinition of the descriptiveness and normativity of rationality, particularly in the fields of economics and management, but more generally in the exploration of human cognition and agency.

1.2 The Origins of Bounded Rationality

Herbert Simon coined the term *bounded rationality* as a concise expression of his critique of the individual decision-making method typically employed in neoclassical economics (Wheeler, 2018). On the one hand, the concept encapsulated his appeal to discard the assumptions of perfect rationality associated with *homo economicus*, which presuppose complete information about entire set of possible events, alternative actions, notional outcomes of the mapping between actions and events (Dosi, Faillo & Marengo, 2020) impeccable memory and infinite computing power (Benincasa, 2020). On the other hand, the expression summarized the proposal to adopt a view of rationality suitable for agents with inherent cognitive limitations (Wheeler, 2018). Ever since the pioneering works that laid the foundations for the behavioural revolution, indeed, Simon highlighted the critical need for a radical transformation of the foundation of economic theory (Simon 1955), by replacing Olympic rationality with the kind of rational behavior that is compatible with the information, computational capacities and memory that are accessible by organisms in their *Umwelt* (Brentari, 2015). Grounded on these premises, bounded rationality has come to address a wide range of descriptive, normative and prescriptive accounts of the actual behavior of decision maker that deviate from the assumptions of neoclassical paradigm.

As emphasized by Wheeler (2018), Simon fundamentally criticized the erroneous shift of attention from "reasoning behavior" to "choice behavior". Firstly, he pointed out the cognitive burdens imposed by subjective expected utility theory, proposing to first assess the effort required to adopt a decision-making procedure against the resources accessible to the organism using it. He then considered essential to assess the accuracy of an organism's performance considering its limited cognitive resources, exploring reasoning models that maintain comparable accuracy within these constraints. In this regard, Simon observes that efficiency requires selecting, among the available options, the one that produces the highest result given the available resources, an option that does not always correspond to the one that obtains the highest overall result once cognitive costs are taken into account.

Though the notion of evaluating decision quality against its costs has largely become central to the mainstream concept of bounded rationality, it has not always been fully understood and sometimes instrumentalized. Simon actually used this argument essentially to advocate for a new research approach to the human cognitive dimension, proposing a different kind of rationality known as "procedural rationality" (1947). Simon's focus on procedural rationality, indeed, led to the exploration of efficient cognitive methods able to balance the accuracy-cost trade-off, based on search procedures, stopping criteria, and the capacity to integrate information during the decision-making process.

Thus, Simon transformed the study of real decision-making processes by focusing on framing these criteria Specifically, he suggested replacing the optimization challenge of maximizing expected utility with a simpler decision-making criterion called *satisficing* (Simon, 1956), adopted by decision-making models with greater predictive capabilities. This method involves reviewing options until one of them reaches or surpasses an endogenously set aspiration level, ensuring a satisfactory outcome, replacing the optimization objective of expected utility theory with a "good enough" outcome. It is in this way that the study of human decision-making should deals with situations in which the preconditions of rationality established by the neoclassical model are not fulfilled since in circumstances where an agent faces decision-making, she does not readily possess every conceivable option and the associated probabilities. Instead, the agent must engage in an exhaustive and often expensive process to uncover these alternatives. As a result of this labor-intensive search, the agent is unable to make the most optimal decision available, due to the incomplete information and limited choices generated from the search (Simon, 1989).

Therefore, starting from the need to account for the actual processes underlying the decisions of individuals (and organisations) (Simon, 1947) who are unable to have a comprehensive knowledge of the entire decision tree, Simon's perspective unveiled a prolific horizon beyond theories of utility maximisation or expected utility. Exploring this trajectory, he was convinced that an adequate understanding of limited human rationality should also clarify the structures of the environment to which the agent must adapt in order to survive; a fundamental ecological assumption of bounded rationality theoretically summarised through the famous "scissor analogy" (Simon, 1990).

Thus, Simon's contribution, focusing on the observation of human decision-making behaviour, prompted the emphasis on the environment. On the one hand, he indeed highlighted how the uncertainty of the environment itself, in its more or less substantial form (Dosi et al., 2020), hinder Olympic rationality. On the other, he asked how do human beings actually make decisions in their daily "wild" environment (Spiliopoulos, 2020), by adopting a naturalistic approach to human cognition and arguing the fundamental thesis that the ways in which an organism handles the structural features of its environment are essential to understanding how deliberation occurs and how effective behavior arises. In this way, Simon believed that both behavioural constraints and environmental structures should be considered in a theory of bounded rationality in relation to each other (Wheeler, 2018). In this approach, behavioural constraints – computational limits such as the cost of searching for the best algorithm to execute, appropriate rules to apply, or satisfactory options to choose – should not be considered independently and separately from the environment. Similarly, ecological structure – which may refer to perceivable invariances of the environment of the task to which an organism is adapted, or to architectural or biological features of the cognitive process responsible for effective behaviour – must be considered in relation to the cognitive features that shape action in that environment.

By contextualizing the effectiveness of rationality with respect to the environment, Simon is considered the initiator of a pragmatic culture (Katsikopoulos, 2014) on bounded rationality, which claim that, before any further evaluation, it must be studied and framed, scientifically and conceptually, within the natural (and cultural) (Remotti, 2019) environment in which emerged and in which it currently operates reflecting its complexity. The environment thus becomes the central focus of rationality, dictating its limits to organisms, that show both species-dependent and universal reactions to its structure (Viale, 2020).

1.3 The Behavioral Turn: A Biased Interpretation of Simon's Legacy?

Simon never developed a complete theory of bounded rationality, inspiring future generations of researchers to contribute to it (Gigerenzer, 2004). His focus on the relationship between cognition, biological characteristics of the agent and its environment places Simon in a position of naturalism with respect to human cognition, agency, behavior, reasoning (and knowledge) (Gigerenzer, 2021); an approach inherited in many fields born or revolutionized by his pioneering work. Indeed, as a pragmatic realist, Simon's observations on reasoning and decision-making gave significant impetus to many disciplines addressing natural or artificial cognition, all of which merged and encapsulated in his formulation of bounded rationality.

His legacy has been primarily inherited by two flourishing interpretations of bounded rationality. On the one hand, the concept has been adopted by a school that wants to empirically test the limits of human rationality by reference to idealistic standards and expose the natural irrationality of human beings. A second tradition seems to have better grasped the ecological Simonian teaching, observing that human behavior is the result of cognition located and inseparable from the environment, and its success must be interpreted in adaptive terms as the result of an evolutionary process of incremental local fitness with it. This second path, which is explored in later chapters, was undertaken by the research programme led by psychologist Gerd Gigerenzer and called *ecological* (first) and *adaptive* (later) *rationality*[1].

The two traditions and schools that have inherited Simon's defeat of perfect rationality by interpreting it in diametrically opposite ways, both refer to the term *heuristics*, a word of Greek origin meaning "which serves to discover or uncover"

[1] The two terms will be used interchangeably and with the same meaning in the present work.

(Gigerenzer, 2021, p.3553). Heuristics are described as "rules of thumb"; simple and efficient rules, encoded by evolutionary processes or learned, that human beings use to make decisions, make judgements or solve problems, especially when faced with complex problems or incomplete information. Starting in the 1970s, Kahneman and Tversky conducted a series of experiments showing the various ways in which human participants' responses to decision-making tasks apparently deviated from appropriate normative standards. These studies founded an influential research trajectory, which also led to a Nobel Prize, which is called *heuristics and biases* and studies heuristics primarily as sources of cognitive biases that can lead to systematic errors in judgement or decision-making. This perspective generally views heuristics as deviations from rationality that often lead to irrational results. Common examples are the *availability heuristic*, a judgmental heuristic used by people to evaluate the frequency of classes or the probability of events (Kahneman, 1973), and the *representativeness heuristic*, according to which the subjective probability of an event, or a sample, is determined by associating it with a known similar one, without considering the actual statistical probability. From a theoretical point of view, these results are explained by Kahneman referring to the *dual-process theory* of cognition (Wason & Evans, 1974): a fictional model of the mind's functioning constituting of both system 2, which is slow, logical, deliberative and can tend towards rationality, and system 1, which is fast, intuitive, non-deliberative and often distorted, and includes heuristics (Kahneman, 2011)

As Gigerenzer points out, proponents of the heuristics and biases program in psychology appropriated the term for their focus on the lack of human rationality, adhering to "the classical view in epistemology that [claims that] axiomatic rationality is normative and psychology strictly descriptive" (Gigerenzer, 2021, p.3554). This, sometimes unintentional, perspective, developed to address what is interpreted as irrational human behavior characterized by biases and formal errors caused by psychological mechanisms such as heuristics, gave rise to the most widespread interpretation of behavioral economics. Although the program criticizes the descriptive component of neoclassical economics, it still maintains its normative view, arguing that deviations from logical rationality result in significant economic losses (Gigerenzer, 2021).

Following this approach, this new behavioral discipline was created in the 1980s and 1990s to pursue the aim of identifying systematic and persistent deviations from logical rationality, which led to the libertarian paternalists (Thaler & Sunstein 2008) and the *nudging* approach to protect citizens from themselves (Gigerenzer 2021). In economic studies, this epistemological position came close to the reductionist line already dominant among neoclassical economists, who in turn, after initial resistance, absorbed the term themselves into the orthodoxy of perfect foresight, by associating satisficing with optimization. According to the reductionist interpretation, the insights of psychology, neuroscience or biology are not at all subversive, they simply allow completely optimal procedures to be modelled by introducing new constraints into standard economic models.

In the interpretation of the second school, which this work shares and which is presented at length below, Simon would have rejected this interpretation on the grounds that human rationality, in order to be appropriate, must be able to describe and predict not only the cognitive mechanisms underlying the behavior of individuals and organizations, but also the relationship between these mechanisms and the environment in which they take place. The *heuristic and bias* approach underestimates the focus on the environment itself by disregarding the actual pragmatic position of "Simonian" bounded rationality, which recognizes the adaptive nature of human thought processes within the constraints of the real world. This is clearly evident in the limitation of experiments to abstract or laboratory contexts, which may underestimate their effectiveness and usefulness in the natural environments where decisions are actually made.

This maybe biased interpretation assumes that the notion of bounded rationality starts from the implicit idea that the full rationality is the benchmark for comparison, suggesting the possibility of identifying certain metrics to measure the limits of an agent's rationality. This misconception of the original naturalistic and pragmatic meaning of bounded rationality seems to be based precisely on the failure to take into account the environment in which human behaviour occurs (Gigerenzer, 2021). Indeed, the real world does not allow, either in practice or in principle, to use rationality as a standard of comparison, since in a radically complex and uncertain environment, rational behaviour is, even conceptually, indefinable (Dosi et al., 2020). Given these premises, this thesis is in the vein of those who advocate going beyond "biased" interpretation of bounded rationality to try to understand how the human mind really works in its (social) environment and how social phenomena arise from the interaction of human minds (Viale, 2000).

1.4 The Ecological Alternative

In stark contrast with the map of systematic biases proposed by the heuristics and biases program, Gigerenzer, Todd, and the ABC group built a program, usually referred to as *fast and frugal heuristics*, in which Simon's bounded rationality is interpreted in an ecological sense, recollocating it into the environment and reformulating its normativity according to its demonstrated effectiveness in relation to the environment itself. The fast and frugal school and the biases and heuristics school both agree that heuristics are simplified or abbreviated procedures but they sharply disagree on whether those simplifications are necessarily a sign of irrationality (Wheeler, 2018). For the fast and frugal program the definition of heuristic comes closer to that of Simon as "tools for finding a proof, solving a novel problem, and planning next year's budget" (Gigerenzer, 2021, p. 3553) capable of identifying what is salient and crucial. Their general goal is then to investigate under what environmental conditions the heuristic's intrinsic bias is well-suited to the task environment, allowing the heuristic to perform effectively and be advantageous compared to longer and more complicated methods.

The fast and frugal program treats heuristics as defined by Simon as algorithmic models of decision-making rather than descriptions of errant effects; to that end, all heuristics in the fast and frugal tradition are conceived to have three building blocks: a search rule, a stopping rule, and a decision rule (Gigerenzer, 2021). From a theoretical point of view, the algorithmic foundation of heuristics is obviously not compatible with Kahneman's dualistic theory of cognition, instead adopting a holistic model of the mind and rejecting to necessarily classify heuristics as non-deliberative cognitive processes (Viale, 2020).

The fast and frugal tradition has therefore proposed a systematic model of ecological rationality, conceptualized as an "adaptive toolbox" (Gigerenze,r 2001) to implement simple strategies able to exploit the informational structure of the natural and social environments. It is an approach that in its *boosting* declination becomes even prescriptive, since it seeks to delineate and propose a decision-making strategy that aims to improve people's competence in making choices by enhancing their use of simple heuristics in a structured and informed way. The big difference with nudging is that in this case people are not pushed to protect themselves from themselves but are educated and trained.

To summarize, in the words of Gigerenzer the ecological perspective entails "the descriptive study of how individuals and institutions actually make decisions and the prescriptive study of the ecological rationality of heuristics" (2021, p. 3564). From a prescriptive point of view, sharing Simon and Newell's (1971) notion of heuristics as expedients that help reduce the time that would normally be required to reach a solution, ecological rationality is primarily measured in terms of frugality, understood as a combination of speed and precision. Emphasizing the fact that heuristic decision-making is always a process of adaptation to the environment, the ecological rationality program, subsequently redefined as adaptive rationality, was welcomed by Simon himself (Gigerenzer et al, 1999) as a "revolution in cognitive science, striking a great blow for sanity in the approach to human rationality"

1.5 Uncertainty outside Small Worlds

> *It is not at all irrelevant whether [boundedness] relates mainly to limitations on the memory that agents carry over from the past, or to algorithmic complexity, or to limited ability of defining preferences over (expected) outcomes. Or, more radically, couldn't it be due to the fact that agents cannot get it fully right (in terms of representation of the environment, etc.) because they are neither an omniscient God nor an approximation to it?*
>
> Dosi & Marengo, 2023

According to Gigerenzer, one of the principles that define Simon's programme of bounded rationality, in addition to studying how the environment, together with the cognitive process, produces the resulting behavior, is to study decision making under uncertainty, not only risk (Gigerenzer, 2001). Having been explained that for Simon, shifting the focus to the ecological nature of cognition and decision-making meant prioritizing the environment, focusing on uncertainty at this point of the discussion is indispensable. Indeed, it is by observing the actual environment in which agents act that the pragmatic culture on bounded rationality realizes that there is a fundamental property of the environment, from the point of view of those who deal with it, that makes it impossible to assume the standard of Olympian rationality and simultaneously allows the researcher to assess a potential superiority of heuristics: uncertainty. In fact, as Gigerenzer observes, the awareness that uncertainty characterizes most of the circumstances in which the economic agent acts was already present even in the more formal formulations of neoclassical economics. Indeed, when Savage (1954), the founder of modern Bayesian decision theory, unlike his great descriptive predecessors Von Neumann and Morgenstern attached a normative interpretation to the set of axioms that laid out, he was extremely careful in limiting his choice theory to *small worlds* (Dosi et al., 2020).

Theoretically, a small world is defined as stationary and isolated portions of the world wherein decision makers know the full set of possible events and can attribute probabilities to them (Savage, 1954) while methodologically it is described by a set of actions indicated through notation (S, C), which denotes the combination of state of the world and the consequences that coincides with that action (Gigerenzer, 2001). This small world is characterized by risk, and therefore in principle predictable and without surprises and they are characterized by the knowledge of all relevant variables, their consequences, and probabilities. It is only in this world of risk that the requirements of neoclassical cationality are satisfied. Exploring outside the large world in which the decision maker operates in his daily life, one realizes that the problems that the agent faces in her real environment are characterized by uncertainty that makes it, by definition, impossible for humans to have certain foresight and does not allow the conditions of knowledge for the axiomatic rationality to be satisfied.

The difference between risk and uncertainty was outlined by Knight (1921). For Knight, risk refers to situations where the probabilities are known, either by design or from relative frequencies in the long run. Ippoliti (2020) reports various existing conceptions of risk, highlighting that all of them include a combination of certainty and uncertainty (p. 99). Specifically, he states that:

> *when we operate under risk, we know what the possible outcomes are and what their probabilities are [...] When we operate under uncertainty, however, the probabilities are not known or are known only with low precision. Unfortunately, only in very rare cases are the probabilities known. Therefore, in a strict sense, the only true cases of risk are ideal cases [...] that refer to events such as dice rolls [...] Ordinary cases, on*

> *the other hand, are characterized by epistemic uncertainty that is not endowed with exact probabilities. Thus, almost all decisions are under uncertainty [...].*
>
> Ippoliti, 2020, p. 100

Unlike risk, technically defined as measurable uncertainty, strong uncertainty that characterizes the large world typically makes the problems to solve ill-defined. This means "the goals are not definite; we don't know what counts as an alternative and how many alternatives there are; it's unclear what the consequences might be and how to estimate their probabilities and utilities" (Viale, 2017a, p. 248). As a matter of fact, strong uncertainty, which characterizes every daily context of our lives like organizing a picnic (Savage 1954, p. 16), involves genuine ignorance and intrinsic inadequacy of the mental models of the agents to fully capture the structure of the environment (Dosi et al., 2020).

Beyond the strong, ontological one, which concerns the structural unpredictability of the intrinsically dynamic natural and social world, other definitions of uncertainty capture the varied nuances with which this dimension manifests itself in the daily life of economic agents. In fact, there is also a less fundamental type of uncertainty defined as epistemic (Viale, 2017b), which pertains to those situations where the individual has not yet obtained all the salient information and thus has not yet entered a small world of risk where uncertainty is merely aleatory because the probability of outcomes is quantifiable. Epistemic uncertainty is the uncertainty that accompanies those who have not yet drawn all the balls from the urn and consequently have no idea how many there are, just as they do not know until they have seen all the swans that there is an "x" probability that the next swan will be black. Epistemic uncertainty characterizes the inductive dimension of information/data gathering, the awareness of which led to the subjective revolution in probability that asserts it exists only because an agent, in conditions of partial ignorance regarding the course of events (read uncertainty), uses it to make predictions (De Finetti, 1931; Galavotti, M. C. 2019). Finally, uncertainty has also been distinguished between substantive and procedural uncertainty (Dosi & Egidi, 1991). Specifically, while the uncertainty concerning the lack of isomorphism between the environment and the agent's model is defined as substantive uncertainty, for an agent in the real world engaged in complex problem-solving activities, there are problem-solving gaps that entail different degrees of procedural uncertainty, with or without substantive uncertainty. Despite uncertainty plaguing the daily life of the economic agent in large worlds, many of Savage's followers, Gigerenzer contends, have ignored it, along with the intractability of problems[2], interpreting violations of logical

[2] A problem is defined as intractable if there is no polynomial-time algorithm to solve it (Sedgewick and Wayne, 2024). Thus, the first general principle that limits axiomatic rationality is computational intractability, which characterizes a well-defined problem like the game of chess.

coherence – a broader group of conditions that include axiomatic rationality, truth-table logic, and rules of probability – as signs of human irrationality. The "Gigerenzian" legacy of Simon instead argues that often these violations of logical rules do not actually matter in the real world but indeed result in effective decision-making strategies in the realm of uncertainty, selected and refined evolutionarily from both a biological and, presumably, cultural process.

Faced with the inevitable uncertainty of everyday life, the pragmatic legacy of Simon therefore argues that instead of perfect rationality, ecological rationality should be focused on, emerged in humans as an adaptation to the problem of decision-making in large worlds. Indeed, in the large world in which we live, problems cannot be faced through optimal computations made by a formal system, but rather through exploratory heuristics characterized by the *less-is-more* principle.

1.6 Less is More

In accordance with Simon's view, Gigerenzer and Brighton (2009) claim that heuristics are efficient cognitive processes that ignore information. This principle, known as the less is more effect, contrasts with the intuitive and widespread belief (which does not take into account uncertainty) that less processing reduces accuracy, and it was discovered through the study of heuristics. *Homo heuristicus* has a bounded mind which ignores part of the available information, is computationally deficient, and usually has no time, but often can handle uncertainty more efficiently and robustly than an unbiased mind relying on more resource-intensive and general-purpose processing strategies. In a number of problems, it seems to be established that simple heuristics are more accurate than standard statistical methods that have the same or more information (Viale, 2020).

This is obviously not always true, but the explanation of their decision-making effectiveness, as well as their ineffectiveness, for the fast and frugal paradigm always depends on the mind-environment relationship as highlighted by evolutionary psychology and behavioral ecology (Marewski & Hoffrage, 2020). Ecological rationality indeed contextualizes from an evolutionary perspective the bounded rationality, "by emphasizing the role of past environments to which we have adapted, the present environment in which we make decisions, and the structure of information as it is processed through decision-making" (Viale, 2020, p. 26). The failures of bounded rationality, the biases certainly common and widespread in everyday life, would not then derive from an intrinsic fallibility of a cognitive system that takes over the decision maker, but from a disabling difference between the environment in which certain strategies have evolved and the environment in which they are adopted today.

It is therefore the mismatch between the environment and the cognitive mechanism that makes it ineffective, and so once again the characteristics of the environment must be considered if one wants to understand how these mechanisms operate. These characteristics, reported by Viale (2020) and identified by Gigerenzer, Todd and ABC group are: uncertainty, which defines the possibility of forecasting an event; redundancy, which indicates the correlation between cues; sample size; and distribution of the cue weights.

It is precisely on the basis of these variables that less can be (and often is) more beneficial, since humans have developed an adaptive mental toolbox packed with simple but accurate tools for making decisions under the uncertainty that characterized prehistoric environments as well as those in which humans live today.

Gigerenzer indeed points out that while in the small worlds of calculable risk the heuristics are subject to the accuracy–effort trade-off that is attributed to them by the heuristic and biases tradition, "under uncertainty, less-is-more effects exist" (2021, p. 3564). The less-is-more effect is explained by Gigerenzer as follows: "assume that two strategies, P and T. P uses only a proper subset of the information that T uses. If P makes more accurate predictions, this is called a less-is-more effect" (2021). This principle is proven true for heuristics in uncertain contexts since, in conditions of uncertainty, the accuracy–effort trade-off is generally replaced by the bias–variance dilemma. Because of this dilemma, which afflicts many complex predictive statistical and algorithmic models, there is a point where more is not better, but harmful, as decomposing the predictive error into a bias and variance components, more effort employed to reduce one component does not lead to better accuracy, as it negatively affects the other one. Instead, Gigerenzer showed how simple heuristics such as take-the-best, as opposed to more elaborate models, "can reduce the error due to variance in several ways" (2021). Thanks to this property, and using less information and computation, he demonstrated that when tested against linear regression (other heuristics were tested against logistic regression or CART with similar results), is able to achieve superior inferential accuracy (Gigerenzer, 2011). To summarize, the adaptive toolbox of heuristics evolved in uncertain contexts, where the accuracy-effort trade-off is not applicable, seems to outperform other models thanks to its capability to capitalize on statistical associations in the environment, or on relationships between the environment and psychological phenomena.

The less-is-more effect that characterizes heuristics has been investigated even in social contexts of one-shot interactions, demonstrating that "even in large-world strategic environments, abandoning normative axioms and Bayesian principles does not necessarily imply irrational behavior" (Spiliopoulos & Hertwig, 2020, p. 268). In these contexts, the possibility of solving the game for the Nash equilibrium, especially if it involves mixed strategies, requires a complexity that is unrealistically manageable by a real decision-maker. Spiliopoulos and Hertwig (2020), by modeling the environment in terms of the size of the games, degree of payoff uncertainty, and degree of harmony, have experimentally proven that heuristic decision-making policies are more common and more robust to strategic and payoff uncertainty than complex decision policies. By verifying that in complex strategic contexts simple rules succeed in relation to certain environmental combinations, Spiliopoulos and Hertwig (2020) have contributed to demonstrating the ecological rationality of heuristics and their adaptive ability to reach goals deriving from ignoring information, which is advantageous in contexts of uncertainty where less can be more.

1.8 From Mind to Society via Homo Heuristicus: A Microfoundation Trajectory

Simon realistic and descriptive approach with respect to the cognitive dimension of human beings was an attempt to finally make economics an empirical science (Simon, Egidi, Viale, and Marris, 1992), starting from its microfoundations. Once the development of research on real decision makers has been outlined, how should this direction be followed? In order to understand the conditions for taking this trajectory, this thesis argues that it is necessary to focus first on another influential position on the consequences for the economy of the cognitive revolution. This different approach, against which it polemises the Simonian view that calls for more empiricism, is Milton Friedman's (1953) instrumental *as-if* approach: a "reactionary" proposal of neoclassical economics.

Friedman's position consists of arguing that individuals, despite maybe not possessing adequate formal tools for calculating the optimum, behave as if they did. This strategy basically involves a continuing commitment to rational microfoundations of economic interactions, together with a radical redefinition of the status of rationality assumptions themselves (Dosi & Marengo, 2023). In fact, as reported by Egidi (1993), Friedman and the Chicago school supported the "as if" hypothesis, with the further assertion that economic facts at the micro-micro level, i.e. individual preferences, were not observable, and, moreover, that they were irrelevant for proving the validity of an economic theory (Friedman, 1953). Essentially for them, "rationality, however defined, rather than being an approximation to the empirical behaviors of purposeful, cognitively quite sophisticated agents, is assumed to be, so to speak, an "objective" property of behaviors in equilibrium" (Dosi & Marengo, 2023, p. 179). Consequently, the theory maintains that the cognitive characteristics of agents are irrelevant to economic science because they would be in any case "teleologically" driven towards a rational behavior compatible with equilibrium states. This rationality would indeed be the result of a not well-specified selection process among various available behavioral alternatives, finally crystallized in the dimension of the economic agency of subjects in equilibrium.

Disregarding the numerous and varied criticisms to which such a poorly constructed theory is exposed in every aspect and assumption of its formulation, that related to the notion of equilibrium and its relationship with the assumption of rationality of agents is, in the opinion of the writer, the most fundamental. This indeed allows to understand which path can be pursued to lead to the antithetical road of an empirical microfoundation of economics.

Since the late nineteenth century, indeed, the standard economic approach has been rooted in the concept of equilibrium. Abstracting from the number of its alternative definitions, the general equilibrium posits that, based on their knowledge, all individuals make plans that are optimal (Benincasa, 2020). The central point is therefore that the representation of human reasoning and decision-making in the economic sphere and the concept of equilibrium are both fundamental interrelate ingredients of the entire neoclassical recipe. The relationship between rational utility maximization and equilibrium is indeed what supports the entire framework of the neoclassical paradigm. This, having taken equilibrium behavior as dogma, has subordinated an *ad hoc* representation of those individual achieving such equilibrium through their behavior, in order to fulfill the prophecy of equilibrium itself. Of the many possibilities, Bentham's proposal seemed to be the one best suited to this end.

> *A multi-millennial tradition of Western thought has asked "how do people behave?" and "how do social organization behave?", from Aristotle to St Augustin, Hume, Adam Smith, Kant, to name only a few giants. However, modern economics – and more recently social sciences colonized by modern economics – have taken up the answer by one of the shallowest thinkers, Bentham: people decide their courses of action by making calculations on the expected pleasures and pains associated with them.*
>
> Dosi et al., 2020, p. 501

Since there cannot be equilibrium without rationality and vice versa, in the as-if theory, it is argued further that even if rationality of agents is not compatible with the characteristics of real agents, its existence is nevertheless justified, as "it must be" the result of an adaptive process, which in turn assumes an instrumental role. Therefore, the formalization of homo economicus is a structural element within a paradigm, that of neoclassical economics, coherent and interdependent with the others assumptions, primarily that of equilibrium. The epistemological coordinates – based on reductionism and isomorphism – and the methodological tools – set on formalization and additivity of individual utility – of the paradigm express the interdependence of these assumptions and are instrumental to its justification and stability.

Given these premises, returning to the alternative of an empirical microfoundation of economics proposed by Simon, it has been inherited by the behavioral economics program, with the goal of replacing the rationality a priori assumptions with more realistic ones. However, as Viale notes, very little psychological realism has been brought into economics by behavioral economists "because there are barriers to psychological realism that are common to neoclassical economics" (Viale, 2017b, p.97). Based on the structural interdependence between rationality and equilibrium argued above, the present work argues that the difficulty in introducing actual realism into economic models, starting from a descriptive attitude towards the cognition and agency of represented human beings, is probably due to not having considered that one cannot simply change an element of a system that is coherent internally. Indeed, if the reference to equilibrium is maintained, then managing of free parameters to improve the realism of the models carried out by behavioral economics risks to resemble an attempt to "add epicycles over epicycles in Ptolemaic astronomy" (Dosi et al., 2020), as it forces the representation refinements to keep it coherent and reconcilable with the other assumptions of an untouched paradigm.

The thesis of the writer is instead that to microfound economics empirically by inserting realism in the representation of cognition and agency of agents, it is essential to refer to a different paradigm from the neoclassical one to which the human definition is one of the fundamental components. It is therefore necessary to first identify a different epistemology and methodology within which to place the alternative to the economic man. This "radical alternative is an anthropology of a homo heuristicus [...] socially embedded, imperfectly learning in a complex evolving environment, and with multiple drivers of his actions" (Dosi et al., 2020). The sections of the work that follow are dedicated to this attempt, focusing on the *heuristic man* in his natural "habitat": organizations.

2 ARTIFICIAL SYSTEMS

2.1 Complex Social Systems

In order for homo heuristicus, and in general a more realistic representation of human beings based on the description of their cognitive, anthropological and socio-contextual characteristics, to be the fundamental microfounding element of the empirical turn in economics, it is essential to reconsider the entire theoretical paradigm to be microfounded, to avoid being constrained by invalidating assumptions incompatible with the microfounding effort itself. It is therefore appropriate to first identify an epistemology and methodology suitable for integrating homo heuristicus as a constituent element of the paradigm and guiding the enterprise. The next sections of this second chapter focus on this aspect, concluding by highlighting a different and promising theoretical paradigm within which to identify phenomena that homo heuristicus can help microfound.

However, it is appropriate to first outline what economic disciplines, in the author's view, should give ontological priority to, meaning by ontology of a research paradigm in economicswhat constitutes economic reality. Once these constituents are clearly identified, it should be easier to find an appropriate epistemology and methodology converging in a paradigm that sets this priority. This work argues that what should have ontological priority, to guide this attempt at microfoundation, are the entities that meet the definition of a system. Beyond the scope of this argument in the context of this thesis is what is meant by the existence of such entities, but it suffices to point out that they seem to occupy a central role in economic reality. In this sense, it is interesting to recall how the centrality of systems in the empirical transformation of the economy from a psychological realism of individuals had already been indicated by Simon himself. It was in fact Simon who inaugurated the strand of research in the Science of the Artificial (Simon, 1996) dedicated to the study of systems and their properties.

A gradual reorientation of the ontological focus on systems has long concerned economics, beginning with management and organizational studies, led by Simon himself, both by discussing systems at a stage of his rich and varied output devoted to them and because a systems perspective was already embedded in those same works on organizations in which he revolutionized cognitive science and the study of human rationality. To effectively situate the microfoundation based on ecological rationality, as well as the current work in management and organization that in the empirical part that follows focuses on heuristics with these intentions, it is natural to see these two aspects of Simon's inquiry as complementary; one on the cognitive characteristics of the individual and the other on the reality formed by the individuals who possess these characteristics: a reality made up of systems. By understanding the concept of system as the economic, social, and organizational reality to which these individuals belong, it becomes fruitful to study the characteristics of these agents, trying to understand how they influence and determine the behavior of the system itself and its high-level phenomena and properties. Accordingly, the author argues that studying ecological rationality within the economic disciplines means giving ontological priority to the systems that make up economic reality and therefore to the collective and aggregate dimensions to which the branches of economics, as a social science, are dedicated by definition. In other terms, the "systemic conception" of economic and social reality must be understood as the horizon of inquiry within which to place the anthropology of homo heuristicus.

According to Simon, the two main systems that constitute economic reality are organisations and the market (Simon, 1947). Much of his discussion is devoted to the former, within which he also explores the rationality of the agents that form it. It is for this reason that cognitive realism and the study of systems merge in the study of organisations from the very beginning. In addition to giving ontological priority to systems and focusing on the organisations among them, it is essential to define certain properties that guide the epistemological approach and methodological tools to be adopted in the study of these systems.

The first and most fundamental characteristic of the social systems that make up the economic world is complexity. Indeed, it is an "artificial" reality made up of complex systems which in turn are composed of complex subsystems, and it must be studied by a science understood as The Science of the Artificial (Simon, 1996). For Simon, the architecture of economic reality is thus made up of complex social systems, defining a complex system as one that consists of many elements that interact in a non-trivial way. System complexity derives strictly from the recognition that at a fundamental ontological level, social systems consist of individuals interacting and establishing connections, relationships and links between them. Social and economic facts and objects – and their dynamics – occur within a network (Biggiero, 2016) and relationship is an essential property that unites any order of events, rules, domains, institutions or behaviours (Strathern, 1995, p. 18).

Having established this fundamental premise about complex social systems, which determines their phenomena, dynamics and properties, these are presented starting from emergence. In complex systems, "the whole is more than the sum of the parts in the weak but important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not trivial to deduce the properties of the whole" (Simon, 1966, p.184). In this informal definition by Simon, the fact that the whole is different coincides with the concept of emergence in the sense that at the level of the whole, something genuinely new is observable; something that cannot be grasped by looking at the individual parts composing the entirety. Indeed, what emerges is brought into existence by the relationship of components and exists within it (Strathern, 1995, p. 18). Although a commonly agreed definition of emergence is absent, considering the elements that contribute to defining this concept and are shared by the research community, the present work refers to the following formulation: "emergence is a process or a state that involves existing entities at different levels of reality, bound by relationships of partial dependence, and capable of manifesting some type of novelty" (Onnis, 2021, p. 19). Regarding this definition, it is appropriate to specify that emergence is an epistemological occurrence, thus a "recognition made by a specific observer, endowed with a particular body of knowledge, suitable theoretical and computational tools, cognitive schemas, goals and intentions, living in a given social, economic, and environmental context" (Pessa, 2016, p.102). Epistemological emergence primarily concerns the relationships that involve the elements of the system. These relationships are focused upon in the following properties.

An important third property of systems is often discussed by Simon, derives from the main and fundamental dimension of complexity and is certainly present in organizations: hierarchy. In Simon's words, a hierarchical system, or hierarchy, is defined as "a system that is composed of interrelated subsystems, each of the latter being in turn hierarchical in structure until we reach some lowest level of elementary subsystem" (Simon, 1996, p.184). Hierarchy is therefore "one of the central structural schemes that the architect of complexity uses" (Simon, 1996). For Simon, the complexity that characterizes systems often takes the form of a hierarchy regardless of the type of system; consequently, every hierarchical system, whether natural or social, has some common properties independent of their specific content. Regarding social systems, formal organizations – business firms, governments, and universities – are quintessentially complex hierarchical social systems because "all have a clearly visible parts-within-parts structure"

(Simon, 1996, p.186). These subsystems are interconnected through interrelationships that go far beyond the chain of command of formal lines of authority. In these systems, as in the more fundamental "elementary units called families" (Simon, 1996) – since "kinship occupies a domain in social life that is considered smaller in scale than the whole" (Strathern, 1995, p. 16) – the rather well-defined hierarchical structure is determined by the denser groups of social interactions (Simon, 1996). Therefore, by observing who interacts with whom, hierarchy can then be defined "in terms of intensity of interaction" (Simon, 1996, p.186). This characteristic distinguishes complex and hierarchical social systems from physical and biological ones, given that for the former, unlike the latter, the relationship between the subsystems that form the hierarchy of the system itself is not defined in spatial terms since it does not require spatial proximity. Indeed, in social systems, "to the extent that interactions are channeled through specialized communications and transportation systems, spatial propinquity becomes less determinative of structure" (Simon, 1996, p.187).

The last essential property of complex systems that assume a hierarchical form is that they are nearly decomposable systems. This characteristic relates to the difference between "the interactions among subsystems [and] the interactions within subsystems, that is, among the parts of those subsystems"(Simon, 1996, p.197). This property states that interactions at various levels are of different natures and is particularly present in organizations since there is "more interaction, on average, between two employees who are members of the same department than between two employees from different departments" (Simon, 1996).

2.2 Epistemological Coordinates

Addressing an ontological landscape populated by complex social systems, for economics, management, and organizational studies, "requires an epistemological and methodological revolution in the way of approaching real or virtual phenomena and the corresponding scientific analysis" (Biggiero, 2016, p. 27).

From an epistemological point of view, the acknowledgment that the typical facts and objects of economic and managerial sciences "are complex in a deep epistemological sense [must necessarily correspond to the commitment to address the] crucial issue of complexity, micro-macro linkages, and the nature of emergent properties"(Biggiero, 2016, p. 9). Thus, considering connecting the study of adaptive rationality to that of systems by investigating the relationship between the cognitition and behaviors of the individual element to the properties and behaviors of the system of which that element is part, when ontological priority is given to these systems it is essential to approach them with a new compatible epistemological perspective. Referring to the properties of complex social systems in the order they were presented in the previous paragraph, an adequate epistemology must account for emergence, hierarchies, near decomposability, and network structure.

Regarding emergence, it was previously specified that it is an epistemic emergence, thus a consequence of complexity that manifests in the observer's explanatory intent at the moment they approach the study of the system. The observer indeed verifies "the need for different levels of description and is unable to explain the behavior at a given level in terms only of the behaviors of components lying at a lower level" (Pessa, 2016 p.103). Epistemic emergence then translates into the necessity to adopt a different epistemological posture from the traditional one inspired by Newtonian physics, which takes into account the impossibility of epistemological reduction and the lack of distributivity of properties among micro and macro. It is indeed only by adopting a non-reductionist approach that we can recognize that "the behavior at the higher level is in principle unpredictable in mechanistic terms and therefore it appears as a genuine novelty" (Pessa, 2016 p.103).

Hierarchy, on the other hand, implies that "in most systems in nature, it is somewhat arbitrary where we break the partition and which subsystems we consider elementary" (Simon, 1962). This means that, from an epistemological point of view, it is not possible to refer to elementary particles on the basis of whose behaviour any explanation of economic reality can be micro-founded. Instead, it is appropriate to decide, in an arbitrary but rigorous manner, which elements of which level are most suitable to use, never exclusively, to explain something without reducing it.

Finally, near decomposability places emphasis on relationships, an element to which, from an epistemological perspective, absolute priority should be given since it is what allows us to explain and address all the other properties and the very nature of the system's complexity. Indeed, "they all assume that the elements constituting the observed phenomenon are not independent and, more strongly, that its relationships are not episodic neither superfluous respect to its meaningful behavior" (Biggiero, 2016, p.10). In other words, as has been effectively noted by other social sciences, primarily anthropology (Strathern, 1988), it is assumed that each observed phenomenon is a structure, and its pattern of relationships is a key factor in understanding its behavior. In other terms, the relationship is thus constitutive of the individual element (Abu-Lughod, 2019), and the positions held by each element within the network, along with the relationships that occur with other elements, should not be overlooked.

2.3 Methodological Revolutions

Considering the epistemological coordinates outlined, which address complexity arising from interactions of which the system is constitute, a complementary methodological commitment must move away from the methodological individualism of neoclassical economics which sees socio-economic phenomena as collections of autonomous particles. This methodological revolution is extensively and thoroughly presented in the handbook *Relational Methodologies and Epistemology in Economics and Management Sciences* (2016), to which this paragraph directly refers.

The methodologies capable of approaching the study of the social sciences as sciences of the artificial are deeply relational, complex and poorly formalized (in the traditional sense of the term). These are presented as a consequence of the epistemological change outlined above but, at the same time, have historically contributed to its foundation, allowing for a different perspective. In the words of one of the authors:

> *Epistemology and methodology are intertwined and influence one another. A new way to look at phenomena often requires new tools to test hypotheses or just to observe and record what was expected to observe or to let new things to be discovered. On the other hand, new tools can allow seeing old things in a new way or seeing new things. The history of science is full of examples for either directions of influence.*
>
> Biggiero, 2016, p. 10

The aforementioned methodologies are called *relational methodologies* because, in line with the above, they take into account the fact, unlike standard statistics, that the elements that make up the system are structurally interconnected and are incompatible with any concept of equilibrium assumed *a priori*. In fact, the authors state that this is a methodological revolution that must break free from neoclassical shackles by approaching cognitive and evolutionary economics. Although this is not an exhaustive list, three of the indicated methodologies are briefly presented here, namely Network Analysis, NK Models and Agent-Based Model. This choice is motivated by the fact that these are the three tools that are most compatible with the epistemological coordinates presented and suitable for the experimental attempt to which the second part of this research is devoted: a practical synthesis of the theoretical vision proposed in this first theoretical section.

Network Analysis (Biggiero, 2016) is used to study the relationships between entities within a network, examining how nodes (individual actors, people, or things) and the links between them affect each other and the larger system. This approach is rooted in graph theory and its essence resides in the properties that a single node acquires, irrespective of its attributes, solely because of its specific position in the network. Focusing on relationships and relative positions in analysis implies recognizing and accepting interdependence among elements.

The NK models (Biggiero, 2016) were originally developed by Stuart Kauffman for biological systems and, after having become a fundamental tool of an interdisciplinary complexity science, were introduced in the field of economics in order to study organizations as complex adaptive systems with interdependent components (Levinthal, 1997). In these models, the number of elements in the system can be influenced by the interconnection of each element with the others. The greater the interconnection, the more complex and rugged the landscape (with numerous local performance peaks) and the more difficult the optimization for the organization is. In practical applications, NK models focus on the interconnections between elements and the consequences of interconnection configurations in complex and adaptive environments. These are methods in which it is demonstrated how the non-linearity of a system's behavior is due precisely to the interaction of the system's different components.

Finally, Agent-Based Simulation Modeling (Agent-Based Models) (Biggiero, 2016) refers to a class of computational models used to simulate the actions and interactions of autonomous agentsin order to assess their effects on the system as a whole. These agents may represent individuals, companies or other entities with the ability to make decisions and interact dynamically with other agents and their environment. Agent Based Models are particularly valuable for exploring complex systems in which individual behaviours, interactions or heterogeneity are important and allow us to observe emergent phenomena in simulated environments. They provide insights into how macro-level models are derived from micro-level interactions and are a powerful set of tools for understanding and predicting the behaviour of complex adaptive systems. One of the main strengths of agent-based modelling is its flexibility in capturing the diversity of decision rules and the complexity of interactions between agents, which are often oversimplified in traditional models.

3 SYNTHESIS: HEURISTIC AGENTS & ORGANIZATIONS

3.1 The Paradigm: Complexity and Evolution

The author believes that a fruitful way to place constrained rationality in its ecological interpretation within the economic, managerial and organizational sciences is to place the analysis of the individual within a collective-level perspective that sees a group, or population of agents, as a system composed of the same naturally characterized individuals. Such an attempt rests on an already explored ontological reconfiguration and a methodological revolution that follows precise epistemological coordinates. Once the ontological priority is reconfigured, the epistemological coordinates oriented, and the methodology recalibrated, it is then indispensable to approach a compatible paradigm, antithetical to the neoclassical one, within which the proposed trajectory of microfoundation can be situated, capable of indicating "what there is to be explained" (Dosi, 2023).

This paper argues that the paradigm that can fruitfully accommodate the Simonian tradition without distorting its meaning and giving it real economic, as well as psychological, significance is one that interprets the economy as an evolving complex system. Its pillars and foundations are enclosed in the manual *The Foundations of Complex Evolutionary Economies,* edited by Giovanni Dosi, to which this chapter directly refers.

It is a formulation that unifies into a structural, unitary, and coherent project many contributions from the varied, boundless, and heterogeneous set of authors of the so-called heterodox tradition in the economic, organizational, and managerial fields, combinig into a single paradigm the perspectives of complexity and evolutionary economics. It is a synthesis that insists on the necessity of being based on empirical evidence, analysis, and the infinite data available in the economic world: a rich, varied, and dynamic reality, in perpetual evolution, involving individuals, organizations, sectors, and the economy, and formed by networks in which heterogeneous boundedly rational agents operate.

This paradigm sees the interpretation of economies as complex evolving systems as the way to fruitfully address the issues that neoclassical theory has not been able to satisfactorily tackle. “They regard, first, the drivers and patterns of change of the capitalistic machine of production and innovation and, second, the mechanisms of coordination among a multitude of self-seeking economic agents often characterized by conflicting interests” (Dosi, 2023).

The proposed paradigm emphasizes understanding the primary forces driving change before attempting to grasp the coordination mechanisms, which are considered inherently imperfect, within economic systems. It’s approach that places a strong emphasis on the succession of technological paradigm and industry and organization transformation of companies continually search for and implement new technologies, organizational methods, and behavioral practices to outperform their competitors.

In this framework, the emergent economic phenomena that concern individual dynamics or larger systems such as sectors or the entire economy are viewed as the result of interactions far from equilibrium among heterogeneous agents. These agents are generally “boundedly rational but always capable of learning, adapting, and innovating with respect to their understandings of the world in which they operate, the technologies they master, their organizational forms, and their behavioral repertoires” (Dosi, 2023). Although this paradigm incorporates the epistemological and methodological framework presented above, it is appropriate to restate some fundamental epistemological principles that supplement those already mentioned and better specify some aspects. The first is realism, understood as the need for necessarily abstract theories not to omit certain general features of reality, which would tend to make the guide conclusions unreliable to the interpretation of reality itself (Dosi, 2023). The second is rather a goal, from which epistemological implications derive: the attempt at microfoundation. This direction, to which this work hopes to contribute by offering some modest insights, presents important peculiarities and pitfalls that are perfectly expressed in the author’s description of the meaning of this attempt:

> *Theories ought to be microfounded, in the sense that they ought to be grounded explicitly (though perhaps indirectly) in a plausible account of what agents do and why they do it. not all 'macro-propositions' should be necessarily micro-founded. On the contrary, in order to go from one level of description to another often requires a lot of further phenomenological restrictions. However, the theories pertaining to each level of description should not be in open conflict with each other.*
>
> Dosi, 2023, p. 14

From a methodological point of view, this approach seeks to capture the dynamics of systems, which it prioritizes to explain phenomena by focusing on the processes that generate them.

The author of the present work believes that an attempt to integrate ecological rationality into the behavior of system elements, as proposed in this thesis, can find its place within investigations aimed at explaining the phenomena that this paradigm seeks to bring to light. These phenomena thus become not only a fruitful interpretative framework for attempts at analysis such as the one proposed in this paper, but also determine and orient its objective. Among these phenomena to be explained, the ones to be referred to through focus on homo heuristicus are those concerning corporate organizations, the original habitat of bounded rationality, the study of which does not find space in general competitive equilibrium models (Biggiero, 2016). This research shares the position of those who argue that, within this paradigm, adaptive rationality can be a founding micro-characteristic of many phenomena, particularly those concerning organizations. Indeed, it is an essential element that characterizes agents and their behavior, which in turn directly or indirectly determines the behavior of the various complex dynamic systems of which they are part; systems that, in turn, are subsystems of larger systems.

3.2 The Unit of Analysis: Corporate Organizations

Organizational, managerial, and economic studies generally refer to bounded rational agents indiscriminately as individual entities or systems composed of these entities, such as organizations. In fact, one can speak of systems as agents when it is useful to consider them in their unity as economic agents operating to explain certain phenomena; a unity that seems to coincide with an attribution of intentionality identifiable in coherent behavior. This coherence, in relation to organizations, is identified, by referring to the metaphor of biological systems, in the adaptive property of these systems, involved in feedback loops with the surrounding environment in which their components participate.

Ecological rationality, therefore, is a characteristic of the agents that make up organizations and must be studied in order to understand how it influences the system based on its structure and the relationships between the agents that make it up. At the same time, however, since organizations are a structured and hierarchical system, in which decisions that give rise to certain behaviors of the firm as an agent are made by managers and specific individuals occupying certain roles in certain subunits of the system, the ecological rationality of the organization may correspond to the bounded rationality of the decision-makers embodying the agency of the organization. Thus, in the context of the study of business organizations, investigations of bounded rationality take two complementary directions: the first concerns its relation to the entire dimension of cognition, reasoning and behavior of individuals in their everyday working lives; the second concerns the description of the bounded rational behavior of the firm-agent/system on the basis of the bounded rationality of the relevant decision-makers.

The premises for such investigations lie in focusing on the collective operational context in which these minds are embedded and, consequently, by referring to the capability-based theory of the firm conceived as an organization as a learning problem-solving entity (Dosi & Marengo, 2023 p.173). In the study of organizations within the evolutionary and complex paradigm, ecological rationality finds its place, along with other building blocks on cognition and agency under more or less uncertain and evolutionary environments, in the theorization of the firm as a behavioral entity (Simon, 1991): a learning agent engaged in problem-solving activities (Dosi & Marengo, 2023). From this perspective, technological knowledge, a central concept in the evolutionary paradigm, corresponds to an idiosyncratic organizational knowledge “incorporated into corporate organizations in the form of shared cognitive frames and organizational routines, evolving over time as a result of learning, innovation, and adaptation” (Dosi & Marengo, 2023, p.5).

3.3 Heuristics in Organizations

> *Individual organizations embody specific ways of solving problems that are often very difficult to replicate in other organizations or even within the organization itself. In turn, organizational knowledge […] is stored to a large extent in the operating procedures and the higher-level rules that firms enact while handling their problem-solving tasks in [different] domains.*
>
> Dosi & Marengo, 2023

Within the framework outlined by Dosi and Marengo, in studying the cognitive and agency characteristics of ecologically rational agents – and consequently what agents (individuals or organisations) do – an important strand concerns the study of heuristics, which are viewed in light of collective learning and problem-solving capabilities tied to an idiosyncratic know-how to producing outputs. This “social” and pragmatic knowledge defines the entire existence of organizations and permeates every level, process, and behavior, and is a central aspect for the contextualization of the study on ecological rationality, manifested in organizations in the form of heuristics.

First, it is important to address the systemic/collective dimension of this peculiar knowledge, by noting that the idiosyncratic capability "to do things" of a company is a property concerning the system as a whole and therefore is not "only incorporated into the heads of organizational members" (Dosi & Marengo, p. 225) and not reducible to the individual skills employed. Instead, the authors suggest circumscribing the element of individual capabilities, in which there is certainly an ecological dimension, within a fundamental class of collective activities in which organizational knowledge of organizations is structured: routines – ubiquitous, repetitive, and organized activities in organizations – in which heuristics (in the general meaning of simple rules of thumb) are supposed to find a primary space for exercise. It is also important to note that there is a difference between heuristics as often depicted in managerial and organizational and the heuristics studied by cognitive and evolutionary psychology. The former refers to collective and successful organizational practices and is often associated with the operational dimension of routines, while the latter are simple decision rules adopted individually by decision-makers primarily in the "wild" (Gigerenzer, Hertwig, and Pachur, 2011). Although there is likely an overlap between these two perspectives in organizations' problem-solving activities, a fruitful research agenda has been outlined to clarify the boundaries and relationships between these two dimensions and interpretations of heuristics (Loock, 2015).

Furthermore, to frame and analyze heuristics within organizations, it must always be remembered that, within the framework outlined by the identified paradigm, organizations are learning systems whose adaptive behavior and transformations are guided by feedback loops in an uncertain and evolving environment. Like heuristics, learning is a phenomenon studied both by research in cognitive and ecologically adaptive rationality and by organizational studies. However, while in many aspects the two perspectives are similar and comparable, being identified with the dynamic aspect of the capability possessed by a firm, organizational learning is also understood as a social phenomenon that cannot be reduced to individual learning processes of the members of the organization (Marengo, 1996); even though this latter individual capability may be a precondition for the system learning dynamics. Given this contextual premise that depicts the representation of the firm as a behavioral entity embedded in an evolving environment rich in radical innovation and where learning is central, bounded rationality in the ecological declination of heuristics is primarily investigated within the uncertain strategic dimension of the organization.

As discussed in the first chapter, the literature identifies uncertainty as a primary condition for the potential superiority of heuristic decision-making, as well as the determinant of the structural impracticality of Olympic rationality; uncertainty which, in the economic reality outlined by the complex and evolutionary paradigm, characterizes the daily life of real decision-makers. The unpredictable nature of the nonlinear dynamics inherent in the complex world populated (though not only) by organizations thus means "that even the analyst, as well as any agent with the same knowledge as the analyst, would not do any better than the heuristic agent. [In these cases,] we are generally unable to dissect deterministic nonlinear and possibly chaotic processes from apparently stochastic components" (Dosi & Marengo, 2023, p.237) and therefore there are no optimal solutions deriving from compromises of accuracy/effort since the unavoidable complexity of infinite interactions generates absolutely unanticipated butterfly effects.

Heuristics adopted in strategic contexts, as previously reported (Spiliopoulos & Hertwig, 2020) depart significantly from the concept of perfectly rational strategy that calculates subgame perfection to achieve a Nash equilibrium. Instead, heuristics concerning strategic decisions in various units and tasks (marketing, R&D, investments, production, sales, etc.) are simple and invariant rules of thumb or higher-level second-degree heuristic, more specialized and often guided by basic heuristics. These heuristics, which are the central elements of the simulation proposal in the second part of this work, being adopted by decision-makers who actually embody the organization behavior with their cognition and agency, have a significant impact on the resultant behavior of the system. Consequently, when focusing on these strategic heuristics, as well as on other problem solving heuristic adopted by high-level decision maker, it does not seem incorrect to associate the agent "organization" with the agent "individual".

3.4 Final Reflections on Natural Agents

The overlap between the decision of an individual in a managerial role and the decision of the organization allows us to refer to a heuristic behavior of the entire organization, which is demonstrated by the fact that "hardly any firm tries to figure out functions such as a demand curve of the overall market, let alone of one's own demand, conditional on the demand curves which competitors figure out, conditional on one's own expectation of their own demand curves, conditional on the expectation of the others' expectations, and so on, to the infinite" (Dosi & Marengo, 2023, p. 245). The unconditionality that characterizes the decision-making mechanisms of economic agents provides a solution to the strategic version of Morgenstern's paradox (1935), which problematizes the infinite process of mutual reflexivity that prevents the prediction of the behavior of an antagonist agent or a system formed by two antagonist agents and the consequent possibility of making a decision. In fact, the process is not reiterated indefinitely because bounded rationality is at work through heuristics and by prescribing the consideration of specific natural constraints (Ippoliti, 2020, p. 112). The unconditional nature of heuristic decisions also allows to say something about the concept of the performativity of theoretical products in economics (Ippoliti, 2020, p. 150) and specifically about its conditions of felicity (Guala, 2016). In particular, the resistance of neoclassical economic theory to self-realization, for example to the self-realization of equilibrium, is due to the fact that this theory does not acquire a fundamental condition that allows agents to self-realize it by implementing it. In addition to the conditions indicated by Brisset (2018), cognitive naturalism embodied in heuristics can be one of the explanations for the failure (at least partial) of the theory, due to the cognitive “limits” of the decision-maker who, by not taking the demand curve into account, cannot realize the equilibrium.

To conclude, before introducing the second part of this thesis devoted to contribute to a microfundation trajectory by preliminary attempt to simulate heuristic agents (organizations), the writer of this work deems it appropriate to emphasize that ecological rationality in the form of heuristics is only one of the building blocks within an “evolutionary view” of cognition, agency, and learning in organizations (Dosi & Marengo, 2023). Ideed, once the Olympian rationality has been abandoned and the representation of real individuals no longer subordinated to the demands of neoclassical dogmas, the reader might legitimately wonder whether the agency and cognition of individuals in organisations is exhausted in the characterisation that refers to ecological rationality. In this regard, in order to avoid falling into the same previous errors and replacing *en bloc* one standardised representation with another equally impoverished one, the author specifies that the adaptive-heuristic dimension emphasised in this work does not naturally exhaust the phenomenological complexity and richness experienced subjectively by people, that guides action and decision-making and of which observable behaviour is a limited objective manifestation.

Moreover, heuristics are by definition situated in a natural and cultural (hence social and technological) environment and, consequently, the empirical study of ecological rationality must be accompanied by other perspectives from the psychological, anthropological and social sciences that together can attempt to capture the complexity of the human mind at least enough to inform managerial, organisational and economic studies. This interdisciplinary enterprise should address the full range of viewpoints relevant to characterising the agent in his or her “economic” life (in the most general sense of the term) by instrumentally selecting certain insights useful in explaining certain phenomena concerning the firm as a problem solver within an evolutionary and complex paradigm It is in this spirit that any stylized theoretical fact relating to human cognition and agency – as in this case, the role of heuristic in decision-making – can help explain higher-level phenomena for which that empirically grounded individual perspective is hypothesized to be relevant.

This thesis by no means argues that heuristics exhaust the dimensions of human reasoning and decision making, nor that homo heuristicus is an exhaustive portrait of a real decision maker. Cognitive naturalism is indeed an interesting and powerful perspective, but it must be read in fruitful combination with other interpretations, for example the anthropological one, which identifies culture as a determining factor that guides human action. Moreover, nature and culture should not be understood independently, as it is now a widespread and established opinion that human beings are naturally cultural (Geertz, 1979). This means that humans are not natural beings who acquired or produced culture at a later stage. Rather, culture – instrumental and symbolic substance – implying social interaction and information exchange, chronologically precedes the completion of brain development in homo sapiens, who "would have been started from the feet" (Remotti, 2019b, p. 18). Therefore, culture has interacted with organic evolution, particularly by directly intervening in the development of the central nervous system, and consequently is an indispensable requirement for the effective functioning of the brain.

Heuristics, as adaptive tools, may be imbued with a cultural dimension from their origin, which may highlight an inevitable relativism in human decision-making processes that varies across cultures, preventing a single, universal representation of the economic agent. The author's opinion is that, however, the attempt to rethink the representation of the economic agent based on a general anthropology of homo heuristicus may still be legitimate for two reasons. The first is that, even though it is certainly not an exhaustive description of cognition, agency, and especially human behavior, an abstraction and generalization based on the most common elements of human action is indispensable for the construction of standardized models required by economic science. Consequently, a significant simplification of the complexity of the cognitive, decision-making, and agency spheres is legitimized as instrumental to the methods and objectives of economics. Naturally, this reduction cannot refer to every dimension of human behavior, but it should focus on a specific and relevant component in the economic reality: decision-making.

The question then is whether a formalizing reduction of the human decision-maker to homo heuristicus is appropriate, or rather if this simplified representation that centers on heuristics captures the most universal characteristics of human decisions (or at least more accurately than a rational pursuit of one's maximum utility). The previous paragraphs have provided an explanation of the greater realism of homo heuristicus compared to homo economicus, a stereotype that, however, responded to the representation of human decision-making and action based on a criterion that aimed to satisfy a requirement of generality, leveraging the plausibility of the universal pursuit of self-interest. The point is that, as in the case of Olympic rationality, also in the case of ecological rationality arise the problem of the condition of universality of the agent's representation, indispensable requirement for the construction of models and simulations that aim to be general. Consequently, referring to the reflection of (Labinaz, 2020), the question is to what extent and in what sense can (bounded) rationality be said to be universal?

For example, in this regard, if one rejects a stratigraphic conception of the relationship between nature and culture that identifies the natural traits of cognition as substantial and impermeable to culture, recognizing instead the human being as naturally cultural (Geertz, 1979) and natural-born cyborg (Clark, 2003), then one cannot be certain of the universality of heuristics adopted in decision-making processes. These cognitive *a priori*, emerged and refined in the dynamic cauldron of social and cultural reality, could vary from place to place, from context to context – as well as from circumstance to circumstance – and therefore are difficult to universalize.

The reflection proposed in conclusion to this theoretical section is thus that homo heuristicus is certainly not a complete representation of the human being; however, its utility for the models, purposes, and intents of economic sciences must first be tested by identifying those cognitive and decision-making agency characteristics as common as possible to every human being. Focusing on the most general heuristics – starting from satisfaction – seems however to be a promising strategy, as these seems general, or at least recurring, traits able to prove a (even minimal) form of universal ecological rationality, and to allow the construction of representations of natural agents based on the similarities that emerge beyond the differences (Remotti, 2019a).

4 SIMULATIONS ON HEURISTIC ORGANIZATIONS

4.1 Premises

The present work, in this second section, aims to adopt the outlined anthropology of a homo heuristicus to investigate the system-level consequences arising from the behavior of a group of agents of which the system is composed and who decide and act by relying on rules of thumb. It is important to clarify that since individuals are simulated using low-sophistication models, which do not allow for the representation of heterogeneity, realistic interactions, and interrelations among the agents, it is not appropriate to describe this as an investigations of the impact of individual heuristic behavior on (complex) system composed by these agents. Instead, what is simulated is rather a population of heuristic agents (organizations), and the properties and dynamics that are focused on are therefore aggregated phenomena concerning the group. Specifically, the role of environmental settings and simulated behaviors is addressed. The hope of the author is that these models can provide a starting point for future research and investigations suited to capturing the “complex social system” dimension to which individuals belong.

Before introducing the analysis, it is also worth retracing the theoretical path outlined so far, which serves as the context and premise for the present investigation.

In chapter 1, the path followed by Simon’s bounded rationality was outlined, identifying ecological rationality as the natural continuation of a call for an empirical approach to be used for descriptively characterizing economic agents.

Subsequently, complex social systems are presented as the fundamental units of economic reality, and a perspective from which to pursue microfoundation starting from real-world agents. The epistemological coordinates preparatory to this endeavor to merge Simon's analysis on cognition and that on organizations as hierarchical near-decomposable complex systems are then outlined. From a methodological point of view, the importance of capturing the real behaviors of agents and their interactions mainly through computer simulations has been advocated in order to obtain results on the emerging behavior of the system.

A suitable paradigm that indicates which phenomena need to be explained and microfounded is then identified. It is a theoretical framework that views the economy as a large evolving complex system, by combining evolutionary and complexity economics, and moves away from the concept of equilibrium to focus on dynamics, heterogeneity, and epistemological emergence.

Within this paradigm, homo heuristicus finds its habitat in organisations, conceived as problem-solving entities that own idiosyncratic organisational knowledge. Among the characteristics of ecologically rational agents in the context of organisations, heuristics assume a prominent role. Indeed, within firms, heuristics, among other characteristics of agency and cognition, constitute an essential building block in the explanation of phenomena affecting firm behaviour.

In the models presented in this section, heuristic behaviors adopted by high-level decision-makers – managers – who incorporate the cognition and agency of the organization are simulated, as was specified in the previous paragraph, since their decisions coincide with the behavior manifested by the firm. Consequently, the agents simulated in the models can be treated indifferently as individuals or organizations: agents facing the uncertainty and complexity of the surrounding environment.

In this phase, populations/systems of performing heuristic agents/organizations in a turbulent/uncertain environment are simulated, starting from the most fundamental heuristic: satisficing. Relative and absolute aspiration levels are set, and uncertainty is generated, and various results concerning observable properties at the aggregate level are observed, analyzed, and interpreted. The objective is to investigate the repercussions of this heuristic decision-making behavior on the system of agents composed of them. The behaviors of agents are progressively sophisticated by incorporating greater realism in the search behavior and the impact of turbulence, imitation heuristics, and exploratory and exploitative search.

4.2 Introduction and Scope: Variations on Satisficing Under Turbulence

The following simulations are presented as variations of the work of Denrell et al. (2023), an interesting proposal considered suitable with the theoretical approach outlined above, and that has inspired the present analyses. Although in the methodological section of the theoretical approach, more sophisticated simulations were indicated as preferable, it was preferred to set up the simulations that follow as variations of the “analytically tractable model of problemistic search” constructed by Denrell et al. (2023) with reference to the proposal of (Posen et al., 2018). This choice is motivated by the fact that for the purposes of this thesis, it was deemed more appropriate and practicable to choose a simpler model, which abstractedness is probably poor in dealing with complexity and relationships as the methodologies presented in the previous sections do, but which is nevertheless intended to be a starting point, providing preliminary results, for more detailed simulations, such as NK models, which can be implemented on the basis of the logic used for the models presented here.

The model of Denrell et al. (2023) was chosen as the starting point for the variations presented in this paper, since the authors themselves propose, as also attempted in another complementary work, to construct simulations with satisficing agents, thus incorporating the anthropology of homo heuristicus into models and simulations. In their original model, the authors state that their aim is to reconnect two streams of the Carnegie tradition, both of which were generated by Simon’s work and unified in Simon: the literature on aspirations and problematic search – why and how much firms search and when they stop (Posen et al. 2018) – and the research on constrained rational search and adaptation in organisations – based on notions of complexity and interdependence between choices – which later led to the implementation of NK models.

The objectives that guided the authors’ work are in fact in harmony with and a fruitful starting point for he proposal of this thesis to characterise real agents as heuristic agents. Specifically, what is proposed here is the simulation of a population of competing (March, 1991, p.81) heuristic agents whose behaviour is then modelled by programming it from the first discovered rule of thumbs which is reported in the literature as the most general and fundamental for guiding decision-making behaviour: satisficing (Simon, 1956). Therefore, what these variations have in common with the original one by Denrell et al. (2023) is that, first of all, the heuristic that is modeled is satisficing. The second feature that the works have in common is that the simulated population, and therefore the individual agents that compose it, are exposed to phenomena of turbulence, which, in the interpretation proposed by this work, coincide with the uncertainty that accompanies the agent’s behaviour in the economy as a complex evolving system. Referring to the devoted paragraph, in this case uncertainty is interpreted as ontological uncertainty due to the non-linearity of the dynamics of society that is also related to the criteria for success of heuristic adaptive rationality.

The simulations presented here, however, propose enriched variations and original elements, responding to the goal of making the reference model more realistic, analyzing new aggregate properties, and providing new results, intervening both on the behavior of the agents and on the characteristics of the environment. In particular, the search behavior of the heuristic agent is addressed by referring to the local search in complex problem-solving tasks (Levinthal, 1997) and to the behavioral theory tradition (Cyert & March, 1963), aiming to make it more consistent with the agent's capabilities and accounting for the knowledge-based learning that characterizes the learning and performance behavior of organizations. Similarly, the impact generated by turbulence on the agents is also refined to appear more plausible.

Furthermore, referring to March's fundamental contribution on organizational learning (March, J.C., 1991) of firms as behavioral entity, exploration and exploitation search behaviors are introduced, always combined with the satisficing heuristic under a turbulent environment, to observe the effectiveness potential of the two strategies.

Finally, with the same aim of increasing the realism of the reference model, intervention is made on those components of search, stopping, and decision rules on which the satisficing heuristic is structured. Based on the literature that indicates satisficing as a more general heuristic on which other more specific heuristics can be combined, the search and stopping rules coincide with other heuristics, integrated into the more general satisficing heuristic. Therefore, these rules are addressed by integrating imitative heuristics, also introducing the dimension of social interaction into the simulation, which characterizes economic reality and which is the fundamental ingredients for the emergence of high-level properties.

In the simulations, satisficing is imagined as a heuristic adopted for decision making in problem solving tasks by managers. Consequently, based on the coincidence identified in the theoretical section between the heuristic decisions made by these individuals and the behavior manifested by organizations, or at least by one of their units, the agents modeled in the simulations can be considered as individuals as much as organizations. Preferably, they are interpreted as organizations within an industry or market or units within the organization.

The next section briefly illustrates the original model and the recurring elements in each model variation, namely intake levels and turbulence. Then, one by one, all the implemented simulations are presented. For each variation, firstly, the rationale behind the introduction of a change or additional element into the model is described; secondly, the logic used to set up the model is explained. Furthermore, specific observable phenomena at population/system level are identified for each model by means of generated graphs. An interpretation of the results is then provided and theoretical and practical implications are outlined to provide guidance to managers and policy makers.

4.3 The General Model

Referring to the structure and the rationale of the model by Denrell et al. (2023), a simple analytically tractable model of problemistic search (Posen et al., 2018) was developed. The model simulates a population of n competing individuals seeks to meet performance goals – aspirations – by drawing a payoff from an exogenously given distribution. The group of agents was modeled in such a way that each tries to achieve satisfactory performance by searching among a large set of alternatives in a dynamic environment where the payoff of an alternative can suddenly change. Guided by the satisficing heuristic, an individual who finds an alternative with “a good enough” performance keeps the alternative and stops searching. If the performance is not satisfactory, the individual keeps searching for a satisfactory alternative. Due to the turbulence characterizing the environment in which the agents perform, it is assumed that the performance of an alternative may suddenly change if a shock occurs. If such a shock turns the performance outcome of the chosen alternative from satisfactory to not satisfactory, the individual resumes the search. Each individual stop searching as soon as her payoff is equal to or greater than her aspiration. Aspirations can be defined either in absolute terms (the aspiration level specifies the level of performance deemed acceptable) or in relative terms (the aspiration level specifies the share of the population the individual wants to belong to). In this context, is considered only the impact of aspiration levels based on absolute performance (performance is above a cutoff value c) that form the basis of the evaluation of an alternative as satisfactory.

4.4 Turbulence and Local Search

In this class of simulations, only the absolute aspiration level is considered, and the impact of turbulence, as well as the behavior of the agent (organization), is modified to make it more realistic in comparison to what companies do in their search processes. In particular, these simulations aim to consider more realistic consequences for the agent, in terms of performance, when hit by shocks. Additionally, by conceptualizing satisficing as a heuristic composed of search, stop, and decision rules, and the aspiration level as a stop rule internal to satisficing, the focus is on the search rule to ensure it accounts for path dependence (Dosi & Marengo, 2023, p. 297) that characterizes organizations’ performance in evolutionary scenarios. The goal is to introduce a more realistic search behavior than the random performance extraction proposed by the original model and to observe the impact of variations in agent behavior on the aggregate phenomenon of the general satisfaction of the population of individuals competing in the long run. Both specifications attempt to insert a correlation in the succession of an agent’s performances to avoid complete independence of each performance, as would occur with a random draw from a uniform performance distribution. The two enrichments of the original model were introduced first independently, in order to isolate the effect of the modified variable. Subsequently, a complete simulation was implemented, combining the two variations, to which further secondary modifications were added in order to obtain a more comprehensive understanding of the observed collective phenomenon.

4.4.1. Baseline Model Set Up

There are n individuals. In period zero, each individual independently draws a performance, $p_{i,0}$, from a performance distribution, $f(p)$. The interpretation is that each individual chooses some alternative, and each alternative is associated with a particular level of performance. For the moment, it is assumed that the performance distribution is the uniform distribution between zero and one. Each individual has aspirations based on the "absolute" level of performance. That is, a performance, $p_{i,t}$ is evaluated as satisfactory if it is above a cutoff value C: $p_{i,t} > c$. A different fixed aspiration level, equal to c for the entire population, is assumed for each period. C can take values in the range 0-1 and varies from one simulation to another.

In each of the following periods, $t = 1, 2, \ldots$ the following happens, for each individual:

- An individual i checks whether the performance in the last period, $p_{i,t-1}$, was satisfactory, i.e., checks whether $p_{i,t-1}$ was above the aspiration. We examine only the aspirations level based on absolute performance.
- If $p_{i,t-1}$ is satisfactory, the individual does not search but keeps the chosen alternative. As a result, $p_{i,t} = p_{i,t-1}$.
- If $p_{i,t-1}$ is not satisfactory, the individual searches during period t. During search, the individual draws another performance level, $p_{i,t}$ from the performance distribution.
- A shock occurs with probability $q \in (0, 1)$, independent across all individuals and time periods. If there is no shock for individual i, the performance associated with the alternative chosen by individual i in period t remains the same, $p_{i,t}$. If a shock occurs for individual i, the performance of the chosen alternative changes.

As in the original work, in this class of variations the focus is on the performance consequences of different aspiration levels and how these performance consequences vary with the probability of a shock, q. The objective is to observe how different aspiration levels impact the expected performance of the population of individuals in the "long-run". Specifically, the expected performance, averaged over all individuals and all periods, during the first T periods is calculated using formula (1): $\pi_T = E\left[\frac{1}{T}\sum_{t=0}^{T}\left(\frac{1}{n}\left(\sum_{i=1}^{n} r_{i,t}\right)\right)\right]$

where ri,t is the reward obtained by individual i in period t. The interest of the analysis lies in πT when T is large. The focus is on the long-run to analyze how shocks, which may be rare, impact the performance consequences of different aspiration levels (in the short run, no shock may occurr).

4.4.2 Turbulence

In this first variant (Figure 1), realism is added to turbulence. To achieve this, turbulence, subjectively akin to uncertainty, is interpreted as stemming from the complexity and unpredictability of the non-linear dynamic of the evolutionary environment. In this case, although it is not impossible for an exogenous shock to positively impact the agent's performance, it is much more likely to negatively affect it. These unpredictable events can be imagined as black swans, such as a financial crisis, a pandemic, a war, but also a scientific discovery that revolutionizes the driving technology of an industry or announces the advent of a technological paradigm shift. Moreover, given the interconnectedness, complexity and dynamism of the economic reality, any small variation propagating through the system can lead to large-scale unpredictable consequences.

Additionally, these shocks can also be exogenous and certainly can also be positive, such as the development or the successful launch of a new disruptive product, the implementation of a new business model or organizational design or a revolutionary change at the top of the chain of command. However, for simplicity, and at the expense of completeness and greater realism, it is assumed that such events negatively impact the current performance of those who experience them, maintaining a certain coherence and plausibility with current performance.

This variation is set up by intervening on the baseline model as follows:

- When a shock occurs (determined by the probability q), the agent's performance is reduced by a percentage between 10% and 20% of its current value. In other words, the agent draws a new performance level performance level, $p_{i,t}$, from the uniform distribution defined in the interval [($p_{i,t}$ - 1) - 20% ($p_{i,t}$ - 1); ($p_{i,t}$ - 1) - 10% ($p_{i,t}$ -1)].

4.4.3 Local Search

In this version (Figure 2), realism is added in agent's search behavior. Having defined satisficing as a fundamental heuristic composed of search, stopping, and decision rules, this proposal aims to better specify the search one. This is done by incorporating an additional local search heuristic, which is widely found in the literature on NK models that simulate agents engaged in complex problem-solving activities (Levinthal, 1997). The search heuristic is included within the rules that compose the more general satisficing heuristic, following the indications from the literature on adaptive cognition and behavior, which describe satisficing as a basic heuristic to be combined with other more specific heuristics. In this case, the satisficing agents' search behavior is guided by a local heuristic in the sense that they search in the space adjacent to current performance (Levinthal, 1997). At the same time, by referring to the famous work "Exploration and Exploitation in Organizational Learning" by March (1991), the local search corresponds to a decrease in performance variability which is in turn associated to knowledge-based learning that makes performance more reliable. This occurs when "work is standardized, as techniques are learned [and therefore] variability is reduced". (March, 1991, p.83)

The agent, therefore, moves in the search space by performing actions with less variability than presented in the original model, performing tasks plausibly correlated to previous performances. This reflects a more realistic agent capable of consistently performing more or less the same, relying on more or less fixed capabilities, while not being fundamentally barred from achieving exceptionally distant results from usual performances. This specification is modeled by changing the nature of the performance distribution, *f(p),* from which the agent draws performances. The normal distribution function is replaced with a normal distribution function centered on the current performance.

This variation is set up by intervening on the baseline model as follows:

- When performance is below the aspiration level *c*, a local search heuristic is applied. The agent draws a new performance from a normal distribution defined in the interval [0-1], centered on the current performance with a fixed variability given by a standard deviation of 0.05, set in order to maintain the consistency of fluctuations among all agents.

4.4.4 Turbulence and Local Search

In this version (Figure 3), the two previous variations are combined into a single model which displays a more realistic impact of turbulence and a more plausible local search behavior.

4.4.5 Exploitation-Driven Organizational Learning

By referring to "Exploration and Exploitation in Organizational Learning" by March (1991), a tendency for agents to improve their own performance is introduced due to exploitation. This variation can represent learning agents who not only reduce the variability of performance due to increasing knowledge (March, 1991, p.83) but base their learning on a strategy of exploitation defined as "the refinement and extension of existing competences, technologies, and paradigms" (March, 1991, p.83). Referring to March's paper, exploration is associated with an increase in the mean of the performance distribution from which a performance is drawn (in case of dissatisfaction or shock).

This variation (Figure 4) is set up by intervening on the baseline model as follows:

- When an agent is dissatisfied, the new performance is drawn from a normal distribution defined in the interval [0;1] with a mean slightly higher than that obtained in the current performance, thus favoring an average improvement. This specification is implemented by centering the performance distribution function on a value 0.05 higher than the current performance and adding a small Gaussian noise to simulate variation.

4.4.6 Heterogeneity at the Start

In this latest variation (Figure 5), more realism is introduced regarding the heterogeneity of agents. Specifically, it represents a population of agents that could correspond to an industry, where organizations are united by the same product offerings. The heterogeneity of the agents is introduced at the beginning of the simulation of this industry and is associated with market concentration. It is imagined that at the start of the simulation, there is a small number of companies that hold the majority of the market share and therefore achieve high performance, while most companies settle for more modest initial performance.

This variation is set up by intervening on the baseline model as follows:

- Initial performance is not randomly distributed to agents according to a uniform distribution between 0 and 1 but rather according to an asymmetric normal distribution with positive skewness. In this way, most agents achieve low initial performance, between 0 and 5, while a minority of market leaders achieve higher performance, identifiable in the right tail of the Gaussian.

4.4.7 Analysis of the Results[3]

Figure 1 shows that a more realistic shock, which negatively impacts performance, results in a substantial change in the optimal aspiration level c^* curve as turbulence levels vary. As obtained in the original model of Denrell et al. (2023), starting from an optimal aspiration level c^* of 1 in the absence of turbulence, the optimal aspiration level decreases as turbulence increases, eventually halving. However, unlike the reference model, the average performance reaches lower values. It can be observed that turbulence causes a general deviation from the average performance curve in the absence of turbulence (used as a reference). This deviation is partially compensated by an increase in the absolute aspiration level. However, the compensation has a U-shaped trend, in fact up to $c = 4$, for each level of turbulence the closeness to the expected performance in the absence of turbulence increases. From $c \geq 4$, however, expected performances deviate progressively and then reconverge when the absolute aspiration reach the highest level.

Figure 2 shows a dynamic opposite to the original simulation. Local search behavior causes the expected performance to decrease with increasing aspiration levels up to a different value for each curve, between 3 and 6, before increasing again to $c = 1$, reaching the starting level of around 0.5. In this case, the best

[3] Figure 6.

expected performance values are obtained for $c = 0$ and $c = 1$, likely due to the local search heuristic.

Figure 3 shows that for each q, the aspiration level yielding the best expected performance is 1, and the best expected performance tends towards a value of 0.5 for each c. For every c level, increasing turbulence decreases the expected performance. This is likely due to the shock being modeled more realistically. Since the turbulence-induced shock negatively impacts agents' performance, reducing it by 10-20%, it is intuitive that more frequent and pervasive shocks negatively affect the aggregate performance. However, increasing the absolute aspiration level under these circumstances seems to allow for progressively compensating for the turbulence-induced debilitation. This dynamic can be explained by the fact that higher aspiration levels trigger a more prolonged and widespread local search behavior within the population. This search heuristic, in contrast to the random search policy of the original model, achieves performance that hardly deviate from the result just obtained even if are equiprobably better or worse. Prolonging search behaviour thus allows more agents to slowly and non-linearly improve their performance and thus partially compensate for the negative impact of turbulence as individuals shift their performance (also) in the opposite direction to it. For each level of turbulence, the worst performance is obtained for low aspiration levels.

Figure 4 shows results consistent with Figure 3 but reflects that a local search heuristic involving exploitation-driven learning – an increase in the average quality of performances – implies a higher probability of achieving higher aspiration levels. This approach assumes that, under certain circumstances, a gradual and controlled increase can lead to overall performance improvement. Indeed, for each turbulence level, higher aspiration levels lead to higher expected performances.

Figure 5 shows that a different heterogeneity at the start – which reflect different market concentration – modeled as an asymmetric distribution of initial performances, does not alter the population dynamics. It only affects the initial average performances due to the changed distribution.

4.4.8 Theoretical Contributions, Practical Orientations and Limitations of Analyses

Unlike the original model, it seems that, by looking at the expected performance of the population, introducing a local search heuristic – corresponding to relying on established organizational capabilities – and a damaging turbulence, *higher aspiration levels are preferable for any level of turbulence*. This appears to be due to the combined effect of shocks that weaken performance and a *local search heuristic* that, by making it unlikely to deviate from previous performance, *limits the risk* of to do an unexpected extremely bad performance and therefore exacerbate the negative impact of turbulence. In this way, the heuristic seems to compensate for the negative impact of turbulence, *especially if the agents ground their knowledge-based learning on exploitation* of existing competences, technologies, and paradigm (albeit the compensation is "slow" as performance improvement is bounded to their own established capabilities). This is possible when higher absolute aspiration levels trigger and sustain a prolonged search for the entire population.

Theoretical Implications: from a theoretical point of view, it seems that *when a population of agents* (individuals or organizations) *try to achieve a satisficing performance by searching locally* and therefore showing reliability in performance, *the more the ambition is encouraged, the less the group suffer from negative shocks* caused by turbulence/uncertainty in the environment. This is crucial, *especially at high levels of turbulence*, when the steepest improvement of expected performance in relation to the increasing of aspiration levels is observed. This is particularly advantageous *when the agents ground* their reliability in performance – based on increasing in knowledge – *on the exploitation of their capabilities*, regardless of the distribution of initial performance.

This result seems to partially contradict what the original simulation shows. Actually, as has been pointed out, the contradiction is apparent since it has been observed that this different dynamic depends only on a different search heuristic assigned to the agents' behavior.

Practical Orientations: what policymakers, decision-makers, or those figures managing a group of performing individuals in turbulent environment might consider from this simulation is that, *in order to understand which level of ambition is best to incentivize* for the long-term performance of the population*, they should evaluate* which type of *search heuristic* the agents' behavior closely approximates or how reliable is their performance output. In the case of a local search heuristic which relies on well-established capabilities, and especially if the agents are inclined to constantly improve by exploiting that capabilities, in order to mitigate the impact of sudden shocks on group's long-term performance it seems appropriate to encourage the agents to be ambitious, and thus be satisfied only with the highest performance achievable. At the same time, and irrespective of the level of ambition incentivized, what is equally essential to encourage is more sustained performance-seeking behavior that can lead to a steady improvement in aggregate performance, regardless of the shocks experienced.

Limitations: the limitations suffered by this model, which certainly need to be considered in a real applied context, mainly concern *the costs for the agents' search*. Indeed, while on one hand, a constant search partially compensates for the negative impact of turbulence, on the other hand, a prolonged search could result in significant individual and collective costs, which could generate *frustration among individuals*, especially in the face of the deterioration of performance achieved with such great effort. This, in turn, could limit the agents' tendency to progress, even reversing the trend.

4.5 Exploration and Exploitation for Relative Aspirations under Turbulence

In this paragraph heterogeneity among agents is introduced in the original model presented in section 4.3. Specifically, two different types of search heuristics are modeled differently. This simulation uses as a reference March's work "Exploration and Exploitation in Organizational Learning" (1991), focusing specifically on the results of the section "Knowledge and Ecologies of Competition". In particular, the model is an attempt to simulate the concepts of *a)* exploration and *b)* exploitation. Exploration is described as the "experimentation with new alternatives. Its returns are uncertain, distant, and often negative" (March, 1991). Exploitation is indeed defined as a strategy refining and extension of existing competences, technologies, and paradigms [...] with positive, proximate, and predictable returns" (March, 1991, p. 85).

Specifically, following the formalization already indicated by March, these two strategies are implemented respectively as *a)* a strategy that increases the variance of the performance distribution function and *b)* a strategy that increases the mean of the performance distribution function. This simulation uses a relative aspiration level, reflecting the competitiveness of the population, and is defined in the original model by Denrell et al. (2023) as the ambition to achieve a performance that is higher than that of w percent of all individuals, reflecting the ecology of competition already studied by March in his work, which is used as a reference in this simulation. The goal is to investigate which strategy is more effective at various levels of competitiveness (determined by the value of w) and with respect to various levels of turbulence. Essentially, it is about simulating the two behaviors examined by March, investigating the validity of the present model based on concordance with results obtained by the author, and observing what results are obtained when turbulence is introduced, which can be conceived as a form of radical uncertainty.

To identify the most effective strategy, the following is visualized:

- The Total Number of Satisfied Agents at the End of the Simulation: this graph shows the total number of agents who exceed their aspiration level at the end of the 50 periods for each value of w and q.
- The Number of Satisfied Explorers at the End of the Simulation: this graph presents the number of explorers who have exceeded their aspiration level at the end of the simulation period, for each combination of w and q. It provides a specific analysis of the effectiveness of explorers in adapting and exceeding their expectations in variable environments by relating the percentage to the total number of satisfied agents. It shows how the riskier approach of explorers translates in terms of meeting aspiration levels in different turbulence contexts.

These variations (Figure 7) are set up by intervening on the baseline model 4.4.1 as follows:

- Each agent starts with a random performance between 0 and 1.
- Agents are randomly classified as exploiters or explorers (50/50 ratio).

- Performance is updated each period based on the type of agent and environmental conditions (*w* and *q*).
- Exploiters: If unsatisfied or hit by shock, these agents implement a strategy of increasing the mean. They do this by drawing the new performance from a normal distribution between 0 and 1 with a center slightly higher (+ 0.05) than the current performance value.
- Explorers: If unsatisfied or hit by shock, explorers adopt the strategy of progressively increasing the variance, responding more and more volatilely to shocks or dissatisfaction. They do this by redrawing from a distribution centered on their current performance, but the variance is increased by 0.01 each time. This increase is cumulative and continues for the duration of the simulation. Therefore, the more often an explorer is unsatisfied or hit by shock, the greater the variance with which their new performance is calculated.
- If an agent's performance exceeds the aspiration level or no shock occurs, the performance is maintained.
- In case of shock for explorers, the criterion for redrawing the new performance is identical to when *p* is less than *c*, whereas for exploiters, when there is a shock, they draw a new performance from a normal distribution centered at p_t - 0.05.

4.5.1 Results and Implications

The graphs show that *the more competitive the environment, the more effective the exploration strategy is.* In fact, the percentage of satisfied explorers out of the total number of satisfied agents increases with the increase of *w*. These results are in line with those obtained by March, although it would be appropriate to test their variability concerning the number of agents. However, looking at the various curves, it is noted that as turbulence increases, the exploratory strategy becomes less effective. The deviation from the number of satisfied explorers in the absence of turbulence grows in the interval of *w* values [0.0 - 0.5], where it reaches a significant gap, and decreases between 0.5 and 1. *The effectiveness of strategies* thus *seems to be influenced by environmental turbulence*. Specifically, *turbulence decreases the effectiveness of the exploratory strategy except in extremely competitive context.*

4.6 Social Heuristics: Imitation

This simulation adopts the framework, structure, and modeling of the original simulation reported in paragraph 4.4.1. As in the previous variations, only the absolute aspiration level is considered, and satisficing is conceptualized as a heuristic formed by search, stop, and decision rules. Following Gigerenzer's suggestion, it is seen as the most fundamental and basic heuristic upon which, or within which, other more specific heuristics can be combined.

Following this intuition, this section presents two variations of the original analytical problem-solving model, in which the stop rule is specified. The stop rule within the satisficing heuristic coincides with the aspiration level already implemented in the original model. Indeed, the aspiration level prescribes that the agent stops once their performance exceeds that value; thereafter, the aspiration level also serves as a decision rule, prescribing the agent to stop their search once exceeded.

However, what has not been specified is how the absolute aspiration level is formed. This variation presents an attempt to specify how the absolute aspiration level is set by introducing another general heuristic, which is then combined with the satisficing heuristic. This additional heuristic is the most widespread and fundamental social behavior strategy: imitation.

Thus, two situations are modeled in which the agent sets their aspiration level by imitating that of others. In this way, a strong social dimension is introduced into the simulation, based on the most fundamental interaction present in human and non-human societies.

4.6.1 Imitate the Successful

Research on organizational learning recognizes imitation as a key driver of knowledge acquisition (Levitt & March, 1988). Indeed, much of the work on imitative behavior in strategy and business research is connected to social learning theory (Bandura, 1977), which has been integrated with a Simonian perspective (Posen et al., 2013), by contending that both search and imitation processes are influenced by the cognitive limitations inherent in boundedly rational agents. As a result, imperfect imitation emerges, characterized by firms' challenges in quickly identifying the right "whom" to imitate in their industry and in flawlessly replicating her strategies ("what" to imitate).

In this model, managers adopt an imitation heuristic, such as "imitate-the-successful" (Gigerenzer & Selten, 2002), based on their cognitive framing of the problem and the decision to imitate, and is influenced by these "adaptive limitations" in choosing whom to imitate. Specifically, the aspiration level of another agent within the population is imitated. Intuitively, this can occur in various circumstances: in competitive contexts, a company in a new market or launching a new product may refer to the target market share of competitors with similar characteristics; a consumer may base their spending on the aspiration level of influential people they wish to emulate; in cooperative contexts, a worker may base their performance in task completion, and adjust their effort accordingly, on the aspiration and satisfaction levels of their colleagues following the rationale: "if it is enough for them, it will be enough for me".

Given the peculiarities of the model, the "imitate-the-successful" heuristics drives the imitation of the aspiration level (the ambition) of who is considered successful, to recreate a specific and widespread situation observed in imitative behaviors among companies and in informal contexts of "how to succeed training" based on influential exemplary models. The rhetoric from successful individuals often highlights that their success was determined by their ambition. In other words, their successful ambition is unconsciously and incorrectly attributed to the aspiration level they set for themselves. Consequently, in daily life is easy to encounter in someone the idea that a correlation between aspiration level and performance actually exists, and that by imitating the aspiration level of a successful person, an influencer for example, one can aspire to achieve the desired success.

The objective of this simulation is to observe how the general level of ambition within a group is influenced by the imitation of others' ambition, by visualizing the following graphs:

- The mode of c over time for all values of q: This graph visualizes the mode of aspiration levels over time, representing the most common aspiration level among agents for each value of q. It helps identify the dominant aspiration level in different turbulence scenarios.
- The average performance over time for all values of q: This graph shows how the average performance of all agents evolves over time for each value of q. It provides insights into how turbulence affects the general ability of agents to maintain or improve their performance.

4.6.2 Random Imitation

Based on the above, this variation (Figure 8) of the baseline model introduces a random imitation heuristic that ensures dissatisfied agents, before continuing their search behavior, occasionally imitate the aspiration level of another agent they deem successful, i.e., one who is performing better than themselves. Thereafter, before proceeding with the search, they check if their current performance is sufficient to sustain that level of satisfaction.

In the simulation, this "imitate-the-successful" heuristic applied to aspiration levels is implemented as follows:

- In period $t0$, the aspiration levels are distributed according to a normal distribution between 0 and 1.
- If an agent's performance is below the absolute aspiration level, with a 10% probability this agent adopts the aspiration level of an influencer who has achieved a better performance in that period, choosing the agent randomly.

4.6.3 Imitation of the Peers

This variant (Figure 9) builds on the concept of social heuristics, according to which agents imitate the aspiration levels of other successful agents, introducing greater realism in the selection criterion of whom to imitate. In this case, an agent can indeed choose to adopt the aspiration level of another agent who is performing better. However, this version introduces greater realism since an agent can decide to imitate the aspiration level only of those who have achieved a better performance than their own but are somehow similar to them. In this way, agents do not delude themselves dreaming an unattainable success by imitating the ambition of someone actually successful but with characteristics vastly different from their own; rather, they are content to imitate their peers, defined as such based on the performance achieved.

In a managerial interpretation, it could be said that they are content to imitate their successful competitors. This specificity introduces a social learning dynamic where agents can adapt their ambitions based on the success of other agents who are judged to be their peers based on a similarity in performance. This heuristic is inspired by imitation logics applied in production planning and marketing, when the target market share (aspiration-satisficing level) related to the market of a new product is predicted by referring (imitating) the market share of similar competitors.

In the model, this characterization is implemented as follows:

- Dissatisfied agents have a 10% probability of imitating the aspiration level of an agent who in the previous period achieved a better performance, provided that the difference between their performances is within a 10% threshold.

4.6.4 Results and Implications

Figure 8 shows that over time, *the dominant aspiration level among the population for each q decreases, and the higher the turbulence, the lower it becomes.* The average aspiration levels also decrease for each *q* over time and are higher for lower levels of turbulence. The average performance of the population in the absence of turbulence immediately stabilizes at a much higher constant value compared to the average performance values when turbulence is present.

Figure 9 shows that *the dominant aspiration level for each q collapses immediately*, much more rapidly than in the previous simulation, and *for each value of q*. The average aspiration levels also decrease much more rapidly for each *q*, and again, the average values are higher for lower levels of turbulence. As in the previous simulation, the mode and average of *c* in the absence of turbulence immediately stabilize at a much higher value compared to turbulent environments, although the value is lower than in the previous version. Comparing the average performance with Figure 8, it is observed that *the peer-imitation logic results in a decrease in average performance for low turbulence values while not affecting the average performance of the population in turbulent environments.*

CONCLUSIONS

The primary objective of this work was to propose a naturalistic perspective on human cognition and agency – more generally on the human mind engaged in decision-making processes – as a foundation for investigating and modeling microeconomic phenomena arising from the interactive behavior of organizations and agents within organizations. The dissertation examined the evolution of bounded rationality in its ecological interpretation and explored both theoretically and practically the possibility of empirically grounding the dynamics of economics as an evolving complex system, starting from a realistic and descriptive attempt to approach the representation and modeling of economic agents.

From the idealized homo economicus, highlighting the relevance of uncertainty, this theoretical journey traced the shift to a more realistic anthropology of homo heuristicus, identifying the heuristics adopted in the decision-making process as building blocks for a mind-society microfoundation trajectory. Subsequently, complex social systems were presented as the fundamental units of economic reality, alongside a perspective from which to pursue microfoundation attempts starting from the representation of real-world agents. The epistemological and methodological coordinates oriented towards emergence and interactions were then outlined, preparatory to the attempt to merge Simon's analysis on cognition with that on organizations as almost decomposable complex hierarchical systems.

A suitable paradigm that indicates which phenomena need to be explained and microfounded was then identified: a theoretical framework that combines evolutionary and complexity economics and conceptualizes the economy as an evolving complex system, denying the concept of equilibrium and focusing on dynamics, heterogeneity, and epistemological emergence. Within this paradigm, homo heuristicus finds its habitat in organizations, determining the resulting problem-solving behavior of the organizations themselves in uncertain environments.

The second part of the thesis attempted to empirically follow the traced theoretical route by incorporating the anthropology of homo heuristicus into an analytically tractable model of problemistic search (Posen et al., 2018) on which agent-based simulations were implemented. With the objective of proposing fruitful variations of the work of Denrell et al. (2023), to which this phase of the thesis is inspired, populations of competing performing agents (organizations) in a turbulent environment were simulated, and, starting from the most fundamental heuristic behavior of satisficing, multiple variations were simulated and investigated. In every simulation, absolute aspiration levels were set, and turbulence was generated. Moreover, local search heuristics (associated with the search criteria of the more general satisficing heuristic), exploitation-driven organizational learning, and heterogeneity of the agents were progressively introduced. Then, results concerning observable properties and dynamics at the aggregate level were observed, analyzed, and interpreted.

By looking at the expected performance of the population, introducing a local search heuristic – corresponding to relying on established organizational capabilities – and damaging shocks caused by the turbulent nature of the environment, higher absolute aspiration levels shared by the entire population result to be preferable for any level of turbulence. The local search heuristic seems to compensate for the negative impact of turbulence, especially if the agents ground their knowledge-based learning on exploitation of existing capabilities. This compensation appear to be tangible when higher absolute aspiration levels trigger and sustain a prolonged search for the entire population.

From a theoretical point of view, it seems that when a population of agents (individuals or organizations) try to achieve a satisficing performance by searching locally and therefore showing reliability in performance, the more the ambition is encouraged, the less the group suffer from negative shocks caused by turbulence/uncertainty of the environment. This is crucial, especially at high levels of turbulence, when the steepest improvement of expected performance in relation to the increasing of aspiration levels is observed. Moreover, a high ambition is particularly advantageous when the agents ground their reliability in performance – based on increasing in knowledge – on the exploitation of their capabilities, regardless of the distribution of initial performance.

Therefore, in order to understand which level of ambition is best to incentivize for the long-term performance of a group of economic agents (individual or organizations), it results fundamental to evaluate which type of search heuristic the agents' behavior closely approximates (by looking also at the reliability of their performance output). In the case of a local search heuristic which relies on well-established capabilities, and especially if the agents are inclined to constantly improve by exploiting their idiosyncratic knowledge, in order to mitigate the impact of sudden shocks on group's long-term performance it seems appropriate to encourage the agents to be ambitious, and thus be satisfied only with the highest performance achievable. At the same time, and irrespective of the level of ambition incentivized, what is equally essential to incentivize is a performance-seeking behavior sustained for as long as possible, that can lead to a steady improvement in aggregate performance, regardless of the shocks experienced.

The behaviors of agents were progressively sophisticated and enriched by incorporating relative aspiration level and exploration and exploitation search behavior. Observing the performances of the agents in relation to all possible combinations of turbulence and different levels of competitiveness (relative aspiration) in the simulated ecological context, the results show that the more competitive the environment, the more effective the exploration strategy is. However, looking at the various curves, it is noted that as turbulence increases, the exploratory strategy becomes less effective. Specifically, the effectiveness of strategies seems to be influenced by environmental turbulence, as it decreases the effectiveness of the exploratory strategy except in extremely competitive contexts.

Finally, a one last variations of the original analytical problem-solving model implemented another general heuristic, combined with the satisficing heuristic, which allowed for the introduction of a stronger social dimension and more realistic interaction between the agents in the simulation. This additional heuristic, used by agents to choose the absolute level of aspiration to pursue, is the most widespread and fundamental social behavior strategy: imitation. In this case, the aspiration levels among the population of agents were observed following the imitative behavior oriented both towards other random successful competitors and their own peers. Regardless of the imitation logic adopted – casual or peer-driven – it turns out that the dominant (and average) aspiration level among the population decreases with each level of environmental turbulence, and the higher the turbulence, the lower it becomes.

In conclusion, the present work revolved around ecological rationality and delved into the theoretical implications of this naturalistic perspective on agents for the study of high-level economic phenomena involving organizationd. Despite the rudimentary nature of the model within this context and some inevitable theoretical and practical limitations, this thesis has yielded some intriguing preliminary insights into the collective dynamics examined. The methodological approach that culminated in these findings traced a possible mind-society trajectory rooted in the anthropology of homo heuristicus and explored through the implementation of simulations of heuristic agents.

APPENDIX

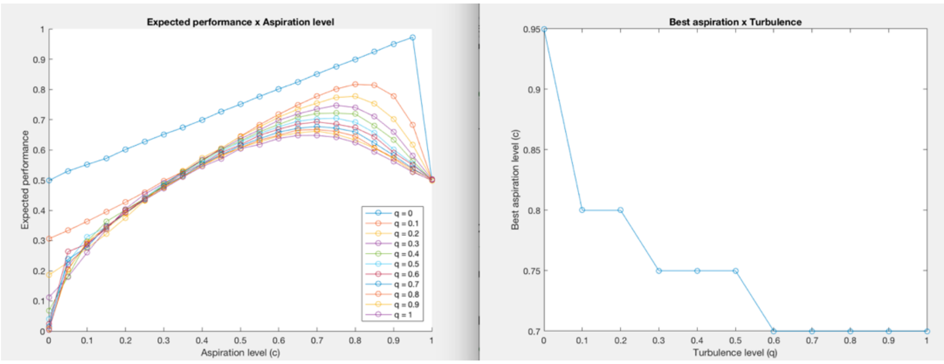

Figure 1

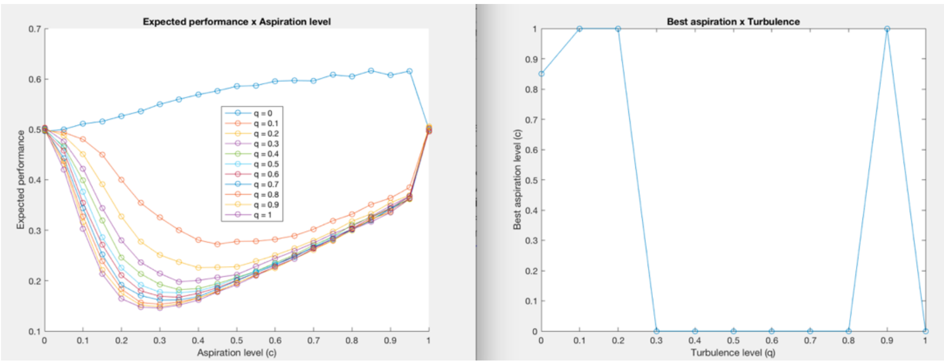

Figure 2

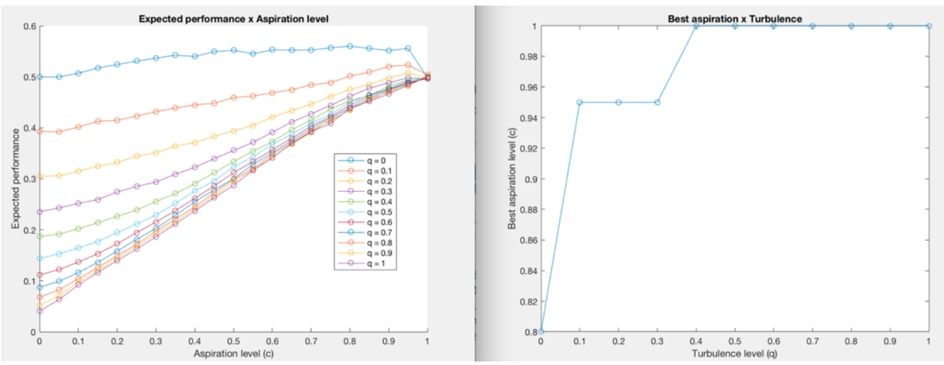

Figure 3

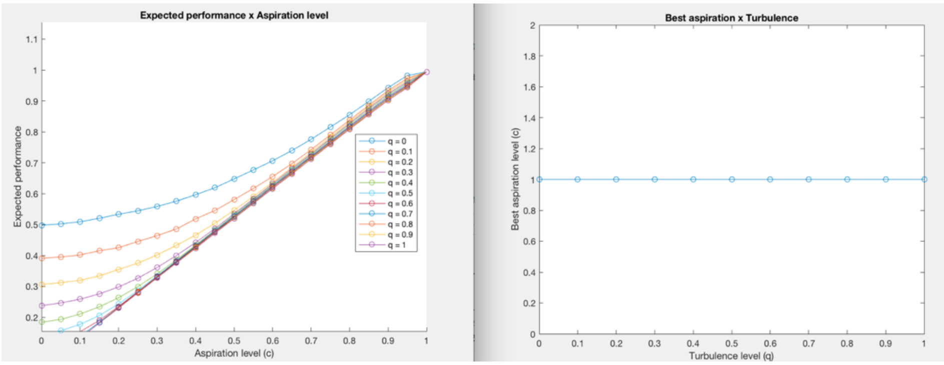

Figure 4

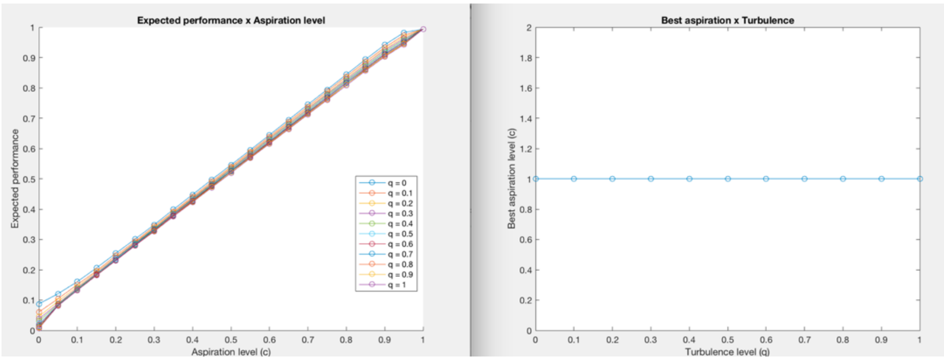

Figure 5

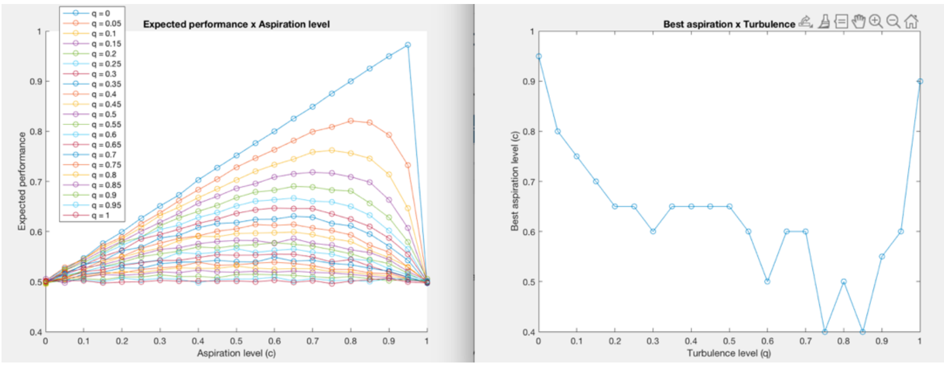

Figure 6[4]

[4] Graphs similar to the those of the original version of the model used as reference for the analysis of the results. The graphs were obtained through an (approximate) reconstruction of the Denrell et al. (2023) simulation with absolute aspiration level.

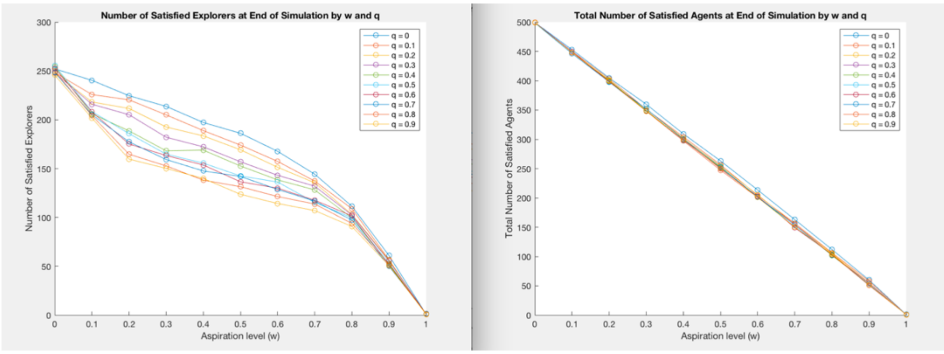

Figure 7

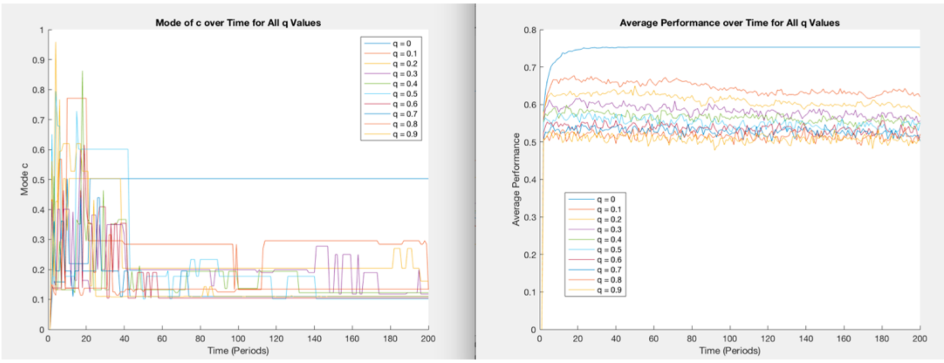

Figure 8

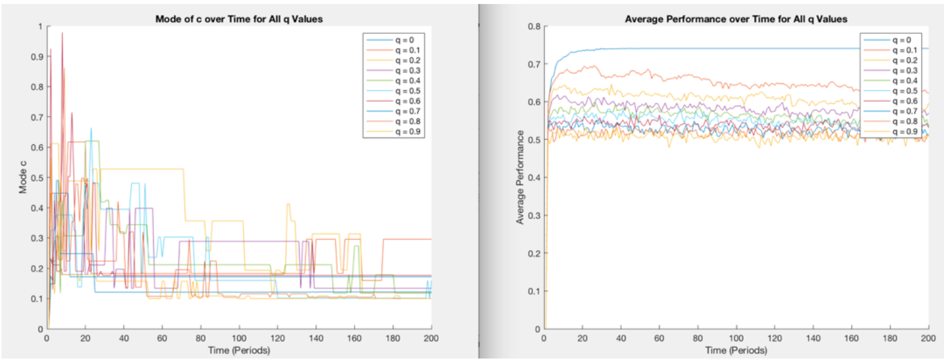

Figure 9

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