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Documents de travail GREDEG
GREDEG Working Papers Series

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GREDEG WP No. 2025-14
https://ideas.repec.org/s/gre/wpaper.html

Behaviours and Learning in Complex Evolving Economies

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Abstract

This paper provides an overview of behaviors and learning of heterogeneous economic agents—whether individuals or firms—within complex evolving economies. It aims to explore the microfoundation of agency and learning, two fundamental aspects that constitutively contribute to the emergence of micro, meso, and macro *stylized facts* of modern capitalist economies, conceived as complex evolving systems. The investigation begins at the individual level, drawing on insights from cognitive and social sciences and identifying relevant micro-evidence concerning the cognitive, psychological, behavioral, and social dimensions of human agency in complex and uncertain environments. It then shifts to the epistemological level *organization*, where individual behaviors and learning are interwoven with those of other members and embedded within the genuinely collective dimensions and emergent properties of the firm—such as organizational capabilities, heuristics, and power configurations—on which the analysis will focus. This perspective interprets the firm as a sort of primitive problem-solving entity and acknowledges that organizational behaviors and learning are "more" than what can be grasped by attending solely to insulated parts. The primary objective of this work is to contribute to a positive theory of behaviors and learning in complex evolving economies, while also offering a fertile ground for theoretical and modeling developments in search of realistic building blocks.

Keywords: Complex Evolving Economies, Firm Behaviour, Human Cognition and Agency, Heuristics, Microfoundations

1 Introduction

This work[1] provides an overview of the phenomena of behaviours and learning, with a particular focus on the latter, within complex evolving economies. To this end, it is first essential to highlight a fundamental interdependence. On the one hand, how agents act and learn are two fundamental aspects to study in order to advance the understanding of the properties of complex evolving economies, ultimately constituted by the agents themselves. At the same time, however, agents' behaviours and learning acquire their own distinctive phenomenological configuration precisely within the economy itself, as a complex evolving system.

Before delving into the exploration of economic agents' behaviours and learning, we outline some preliminary considerations regarding the theoretical framework in which these two phenomena are embedded and the epistemological approach we adopt.

By complexity, we primarily refer to the most minimalist notion of the concept, which, at the very least, acknowledges that the economy consists of multiple interacting actors. As Herbert Simon puts it:

[1] This work significantly draws upon Chapter 4 by Dosi and Marengo in Dosi (2023).

> Roughly, by a complex system, I mean one made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole.
>
> (Simon, 1962, p. 468)

Giving priority to complex systems implies focusing on the phenomena and properties that characterize these entities. This means addressing the "properties of the whole", which are generally emergent (i.e., collective properties arising from the local interaction among multiple agents) and cannot be attributed to the intentionality of any individual agent or group of agents (see Lane, 1993; Prigogine and Nicolis, 1977; Camazine *et al*., 2001). In fact, the evolutionary paradigm precisely examines the properties of endogenously changing multi-agent systems.

What is theoretically captured as emergent phenomena and properties consists of regularities manifesting at different levels of aggregation and analysis, some of which serve the epistemological role of *stylized facts* (Dosi, 2023), which we advocate as guides for research in the economic discipline. The various scales and levels of granularity at which idiosyncratic emergent properties arise often concern different subsystems—also complex and evolving (or at least adaptive) to varying degrees—that constitute and populate complex evolving economies. These subsystems include markets, industries, organizations, institutions and the diverse range of systems defined by their interconnectedness.[2]

The relationship between higher-level manifested regularities and lower-level evolutionary behaviours and processes frequently unfolds as a complex co-evolution across layers of analysis and time scales. Indeed, across different temporal frames, the phenomena and dynamics that contribute to the emergence of higher-level patterns can themselves be emergent properties at their own level of analysis.

These emergent regularities at various levels may be embedded in theories that provide interpretations of crucial stylized facts and their links, thereby guiding the focus within the dynamics through which different lower-level factors—including behaviours and processes (such as learning) of the agents involved—contribute to the emergence of the same stylized facts under consideration. These theories, which ultimately aim to address some of the most fundamental economic questions (Dosi, 2023), can eventually be formalized and tested through *metaphorical* (Bouchaud, 2025) models that highlight the mechanisms underlying the proposed explanations.

Although these models are not necessarily empirically grounded in all their parts, we are convinced that they must remain plausible. Consequently, the ideal theories and models we have in mind aspire to be structural, in the sense that they explicitly build upon representations of what agents do, how they adjust, and how they interact. At the very least, the behaviours and processes modelled must not in open conflict with empirical observations of what agents do in reality and why they do it, nor with findings from alternative consistent theories and models corresponding to different layers of description. As a result, theories should be microfounded—that is, explicitly (although possibly indirectly) based on reasonable accounts of economic agent behaviour. Naturally, not all macro-level propositions necessarily require microfoundations; nonetheless, we are confident that this effort, together with the guidance from stylized facts, helps avoid becoming locked in the path-dependent

[2] The modern capitalist economic system and the entities composing it are indeed genuinely evolving: new elements, new sub-entities, new morphologies are bound to appear along the course of evolution. Indeed, evolution is a multi-scale phenomenon, ranging from microeconomic behaviours to the features of industrial structures and dynamics, and consequently important stylized facts emerge at various levels. Those most directly relevant to this work are at the micro and meso levels and concern accumulation of capabilities, coevolution of technologies and organizational forms. These represent anatomical cross-sections of the economic system and its engine, whose explanation allows shedding light on the physiognomy, functioning and transformation of the socio-economic capitalistic organization.

cage of unfounded theories that ultimately resort to constructing ever more "Ptolemaic epicycles" to avoid falsification.

In this regard, we advocate that realism is a virtue and, in many respects, a necessity. Although theories are inherently abstract and admit less of reality than they omit, certain broad features of reality must not be disregarded without consequence. Omitting them risks producing conclusions that are unreliable as guides for interpreting reality, even if they remain instructive in illustrating important mechanisms or providing other analytical insights. In this sense, our commitment is to a phenomenological description of micro-behaviours that adheres as closely as possible to the available micro-evidence.

Given these premises, this work addresses the behaviours and learning processes of heterogeneous economic agents—whether individuals or firms—acting and interacting within complex evolving economies: two aspects that play a constitutive role in the emergence of micro, meso, and macro stylized facts. Therefore, adopting a genuinely realist epistemological stance, we explore the behaviours and learning processes of human beings and organizations through a microfoundational lens.

The analysis begins with individual-level behaviours and learning, investigating, as far as possible, the very foundations of these phenomena. This will be done by identifying—through a descriptive naturalistic approach to the study of economic human agents—micro-evidence related to the cognitive, psychological, and behavioural dimensions, as well as the social and environmental contexts in which individual actors perceive (and feel), judge, decide, act and learn. Such an approach contributes to a deeper understanding of individual behaviour and learning in complex evolving economies.

Subsequently, the focus shifts from the individual level of analysis to the collective one. At this stage, unlike at the individual scale, the key distinction lies in the fact that behaviours and processes that pertain to collective entities generally cannot be solely reduced to the conscious, or unconscious, intentionality of any particular individual. When addressing the behaviour and learning of a collective agent such as a firm, we interpret these two phenomena more appropriately as properties emerging at the aggregate level *organization*.

This does not mean that individual agents are not responsible for collective agency and learning, quite the opposite. Organizations are indeed conceived as social systems and, more precisely, as complex adaptive systems ultimately composed of human beings. Within organizations, individual behaviour and learning processes are still occurring at the level of the single agent, just as the cognitive, psychological, and social characteristics that contribute to their configuration are always present. At the same time, however, the intentions, decisions, actions, and dynamics of each individual—along with their unique personal dispositions—interact with those of others, shaping one another and often manifesting in an unpredictable collective form. Moreover, individual agency is embedded within and interwoven with multiple dimensions, features, and idiosyncratic properties of the entity **"**firm**"** (often emergent themselves), such as rules, routines, managerial heuristics, hierarchy and power, organizational knowledge, memory, capabilities etc.

Therefore, when we talk about the behaviour and learning of firms, we refer to properties that are inherently emergent at the collective level of corporate organization. These properties result from the interplay of multiple interdependent and co-evolving elements and often persist over time, typically extending beyond the sole contributions of any single individual.

Naturally, for every behaviour, process, dynamic, or phenomenon concerning the firm, there will be individuals whose decisions—which may be more impactful than those of others depending on the context—will contribute more significantly to some specific emerging properties. A clear example is short-term strategic decision-making, where the decision of a single manager—and consequently, her cognitive and behavioural traits, such as the use of heuristics—plays a crucial role in shaping the firm’s emergent strategic behaviour. However, even in such cases, the individual decision is itself

shaped by the organizational rules which govern it and routines within which it occurs, the firm's capabilities, memory, and the locally stored knowledge on which is grounded, the cultural and power configurations in which it is embedded, and the organizational hierarchy and form in which it takes place. Thus, to conclude, when adopting the aggregate level of analysis *organization*, we ultimately conceptualize behaviour and learning as belonging to the organization as a sort of primitive entity (Dosi *et al.*, 2020b).

Having clarified the general architecture of this work, the final preliminary consideration concerns learning. On the one hand, we refer to behaviour in a broad sense; on the other, among the various processes, we specifically focus on learning, which plays a central role throughout the development of the discussion. This choice stems from our recognition of learning as a recurring phenomenon in complex and evolving environments, such as economic systems. As a result, among the various emergent properties addressed within the theoretical framework to which this work refers (for a comprehensive account, see Dosi, 2023), learning assumes a distinctive centrality and, in fact, will serve as the guiding thread of the following examination. Accordingly, the discussion begins with an exploration of the inherently imperfect and path-dependent learning which characterizes any type of agent operating in contemporary capitalist economies, highlighting some of its key features, which equally apply to both the individual and collective levels. These features are crucial in shaping the form that learning takes within an evolutionary context, as it emerges from the actions of agents interacting within such an environment.

2 Learning

In the most generic terms, learning may occur in all circumstances whereby agents have an imperfect understanding of the world in which they operate—either due to (i) lack of information about it, or, more fundamentally, to (ii) an imprecise knowledge of its structure; or (iii) when they master only a limited repertoire of actions in order to cope with whatever problem they face—as compared to the set of actions that an omniscient observer would be able to conceive; or, finally, (iv) when they have only a blurred and changing understanding of what their goals and preferences are.

It is straightforward that learning, so defined, is a ubiquitous characteristic of most economic and, generally, social environments, with the remarkable exception of those postulated by the most extreme forms of economic modelling, such as those assuming rational expectations or canonical game-theoretic equilibria. But, even in the latter cases—and neglecting any issue of empirical realism of the underlying assumptions—it is natural to ask how did agents learn in the first place about e.g., the "true model" of the world in a Rational Expectation set-up, or the extensive form of a particular game?

Of course, learning acquires even greater importance in *complex* and explicitly *evolutionary* environments (which we believe be indeed the general case), where a) heterogeneous agents systematically display various forms of "bounded rationality"; b) there is a persistent appearance of novelties, both as exogenous shocks, and, more important, as the result of technological, behavioural and organizational innovations by the agents themselves; c) markets (and other interaction arrangements) perform as selection mechanisms; d) aggregate regularities are primarily emergent properties stemming from out-of-equilibrium interactions (more detailed discussions are in Dosi, 2023).

The general thrust of the argument throughout this work is that learning crucially entails cognitive activities of construction and modification of mental models and behavioural patterns hardly reducible to well defined problems of choice, even if under imperfect information and probabilizable risk. Rather, individual and organizational behaviours are generally characterised by heuristics and routines, which robust adaptive action patterns in changing and complex environments.

The very notion of "bounded rationality" commits from the start to an implicit idea that "full rationality" is the underlying yardstick for comparison. In turn, this implies the possibility of

identifying some metrics upon which "boundedness" and, dynamically, learning efforts could be measured and assessed. In quite a few circumstances this can be fruitfully done[3], but in others it might not be possible either in practice or even in principle. In particular, this applies to search and learning in complex functional spaces (as many problems within and outside the economic arena commonly do)[4]. And, of course, this is also the case of most problems involving discovery and/or adaptation to novelty.

Since these features are typical of evolutionary environments, an implication is that one might need to go well beyond a restricted notion of "bounded rationality", simply characterized as an imperfect approximation to a supposedly "full" one—which, in these circumstances, one is even unable to define what it should precisely be.

But then, again, how does one conceptualize and represent learning agents in these circumstances?

2.1 Specific features of learning in complex evolving environment

To effectively address this issue, we deem it necessary to first examine a preliminary question: what is learning about?

Learning is a multifaceted and multidimensional process[5] that involves acquiring knowledge in different areas, ranging from states of the world to other agents' behaviours, problem-solving, and one's own preferences. Moreover, learning can occur in different state-spaces, including the space of representations or models of the world, the space of parameters within a given model, the space of actions, and the space of realized performance outcomes.

Additionally, it can involve searching for better representations, refining parameter estimates, selecting among alternative actions, or adapting based on performance dynamics. Furthermore, different objects of learning imply different learning processes that may require distinct mechanisms, which, in turn, shape the dynamics of learning over time.

Finally, learning processes can be constrained within fixed domains or evolve in open-ended dynamics with constant novelty. Different mechanisms, ranging from simple adaptation to complex reasoning, shape learning outcomes. No universally robust empirical generalization exists to fully capture all the dimensions of learning process and the various forms the process can take. However, despite the difficulty in addressing this economic phenomenon, the following sections present an overview of some of the most relevant features of learning in complex evolving environments, which are useful for understanding its specific emergent configuration in complex evolving economies.

2.1.1 Substantive and procedural uncertainty

One angle from which to look at learning processes focuses on the levels of cognitive and *problem-solving complexity* and its causes. It is useful to distinguish between the two different, albeit interrelated, sets of causes that make problems "hard", and that match our earlier distinction between knowledge-gaps and problem-solving gaps. In general, knowledge gaps arise from the lack of isomorphism between the environment and the agent's model of it. This is what we call in Dosi and Egidi (1991), paraphrasing H. Simon, *substantive uncertainty.* In turn, one may further distinguish between *weak* uncertainty (i.e., probabilizable risk) and *strong* uncertainty, involving genuine

[3] Promising results stem from a better understanding of the formal structure of problem-solving heuristics (c.f. e.g., Pearl, 1984, Vassilakis, 1997, and, in a suggestive experimentally based instance, Cohen and Bacdayan, 1994, and Egidi, 1996)..
[4] For example, in Dosi *et al.* (1994) we consider quantity-and price-setting as cases to the point.
[5] Here, we limit ourselves to discussing learning at a relatively high level of generality, consistent with the objectives of this work. For an exhaustive inquiry into learning processes, including taxonomies and exploration of learning domains (about states of the world, decision rules, technological learning, etc.) and associated representations and models, see specifically Dosi *et al*., (2005), and more broadly Dosi (2023).

ignorance and intrinsic inadequacy of the mental models of the agents to fully capture the informational architecture of the environment.

Conversely, problem-solving gaps entail different degrees of *procedural uncertainty*, with or without substantive uncertainty (an impressionistic taxonomy is presented in Dosi, 2023). The distinction is clear, for example, with reference to puzzles like the Rubik cube. Here the structure of the problem is rather simple, ones the rules are known, and there is no substantive uncertainty: rather, solving the problem itself is the difficult task, involving relatively complex skills of sub-problem decomposition and sophisticated logical skills (Dosi and Egidi, 1991). Similar considerations apply to activities like theorem-proving and also, nearer to the economist's concerns, to many tasks associated with technological innovation such as the design and implementation of new products and processes.

The distinction helps also illuminating the somewhat different nature of the related learning processes. In the case of procedural uncertainty, they concern primarily the development of problem-solving skills and heuristics.

Conversely when the latter can be reduced to rather simple and well understood algorithms, but uncertainty is primarily substantive, learning regards essentially the representation and framing of the problem.[6]

2.1.2 Learning and the "logic of appropriateness"

We have already mentioned that, in most circumstances, knowledge-gaps and problem-solving gaps are often related.

First of all, they are likely to appear together in evolutionary environments: it is straightforward that the continuous possibility of arrival of innovations implies "strong" substantive uncertainty, but, relatedly, this implies a symmetric procedural uncertainty ("How can I cope with a changed environment? How can I, myself, innovate?").

Moreover, the psychological evidence shows, the knowledge of the "structure" of the problem and problem-solving capabilities strongly influence each other: the way we perceive the structure of the problem largely depends on the kind of problem-solving skills we possess and, conversely, the problem-solving skills we develop are shaped by the ways we frame the problem (there is a germane discussion of the intertwining between a particular representation and a particular expertise in Lane *et al*., 1996.)

The phenomenon hints at a more general property of decision making and learning which James March and Johan Olsen have named "*logic of appropriateness*". As opposed to the archetypical decision process based on the evaluation of alternatives in terms consequences for utilities (i.e. the "logic of consequences"), in the appropriateness logic:

> Individuals and organizations fulfill identities, they follow rules or procedures that they see as appropriate to the situation...[while] neither preferences as they are normally conceived nor expectations of future consequences enter directly into the calculus... Decision makers are imagined to ask (explicitly or implicitly) three questions:
>
> 1) The question of recognition: what kind of situation is this?
>
> 2) The question of identity: what kind of person am I? Or what kind of organization is this?
>
> 3) The question of rules: what does a person such as I, or an organization such as this, do in a situation such as this?"

[6] Incidentally note that the standard decision theoretic tool kit handles essentially substantive uncertainty (in its "weak" form) but is much less apt to deal with learning in the space of problem-solving procedures.

(March, 1994, p. 57-8)

Note that under the logic of appropriateness, so defined, an important part of learning is about the understanding and implementation of the appropriate rules and, in a broader perspective, entails the co-evolution of identities, representations, and rules.

It is our belief that, indeed, the *logic of appropriateness* informs a good many individual and organizational behaviours and, to anticipate one of our conclusions, an urgent task ahead is to formally incorporate it into evolutionary theorizing.

2.1.3 Information, knowledge, and learning [7]

There exists a fundamental distinction between information and knowledge. The former entails well stated and codified propositions about (i) states-of-the world (e.g., "it is raining"), (ii) properties of nature (e.g., "...A causes B..."); (iii) identities of the other agents ("I know Mr. X and he is a crook...") and (iv) explicit algorithms on how to do things.[8] Conversely, knowledge, in the definition we propose here, includes a) cognitive categories; b) codes of interpretation of the information itself; c) tacit skills, and d) search and problem-solving heuristics irreducible to well defined algorithms.

So, for example, the few hundred pages of demonstration of the last Fermat theorem would come under the heading of "information". Having said that, only some dozen mathematicians in the world will have adequate *knowledge* to understand and evaluate it. On the other hand, a chimpanzee, facing those same pages of information might just feel like eating them, and the vast majority of human beings would fall somewhere in between these two extremes. Similarly, a handbook on "how to produce microprocessors" is "information", while knowledge concerns the pre-existing ability of the reader to understand and implement the instructions contained therein.

Moreover, in this definition, knowledge includes tacit and rather automatic skills like operating a particular machine or correctly driving a car to overtake another one (without stopping first in order to solve the appropriate system of differential equations). Finally, it includes "visions" and ill-defined rules of search, like those involved in most activities of scientific discovery, and in technological and organizational innovation (e.g., proving a *new* theorem, designing a *new* kind of car, figuring out the behavioural patterns of a *new* kind of crook that has appeared on the financial market...).

Here, knowledge is to varying degrees tacit, at the very least in the sense that the agent itself, and even a very sophisticated observer, would find it very hard to explicitly state the sequence of procedures by which information is coded, behavioural patterns are formed, problems are solved, etc.

In fact, as Winter (1987) suggests, varying degrees of tacitness together with other dimensions (see Table 1) provide a sort of interpretative grid by which to classify different types of knowledge.

In this perspective, learning has three interrelated meanings.

Table 1 - Taxonomic Dimensions of Knowledge Assets

Tacit	----------	Articulable
Not teachable	----------	Teachable
Not articulated	----------	Articulated
Not observable in use	----------	Observable in use

[7] This paragraph is largely drawn from Dosi (1998), and Dosi *et al.* (2005).

[8] These four sets correspond quite closely to the codified aspects of Lundvall's taxonomy, distinguishing *know-what, know-why, know-who* and *know-how* (Lundvall, 1992).

Complex	----------	Simple
An element of a system	----------	Independent

Source: Winter (1987, p. 170)

First, rather obviously, it might involve, as in the conventional view, the acquisition of more information (conditional on the ability of correctly interpreting it).

Second, it entails various forms of augmentation of knowledge *stricto sensu* (which might well be independent from any arrival of new pieces of information).

Third, it might concern the articulation and codification of previously tacit knowledge (learning here involves so to speak "knowing better what you know").

In particular, this third aspect has drawn a lively debate concerning whether new information technologies accelerate the pace of codification and fundamentally upset the relative importance in contemporary economies between "information" and "tacit knowledge" (for different views on this point, cf. e.g., Foray and Lundvall, 1996; and several contributions therein, Hicks, 1995; Pavitt, 1992).

3 Individual level-analysis: "Stylised facts" from cognitive and social sciences as building blocks of evolutionary theories of agency and learning in complex evolving economies

As already anticipated above, this work aims to provide an overview of the phenomena of behaviours and learning which take place within complex evolving economies. With the objective of addressing the very foundations of both individual and organizational behaviours and learning processes, let us begin by analyzing the former.

This investigation is being carried out in the spirit of responding to the call for "economics as an empirical discipline" (Simon, 1981), as Herbert Simon continuously advocated throughout his life. Undoubtedly, we aim to uphold the scientific soundness of this approach, despite the inevitable phenomenological diversity of cognitive and behavioural representations that may emerge. For instance, this work significantly refers to the broad framework of bounded rationality; however, the way in which "rationality is bounded" is naturally likely to depend on multiple factors: the nature of the decision problem at hand, the context in which the decision-maker operates, the pre-existing learning skills of the agents, and so forth.

So, what about the alternative advocated here?

Adopting a descriptive naturalistic perspective on the study of economic human agents, we present below some micro-evidence related to cognitive, psychological, and behavioural dimensions, as well as the social and environmental contexts in which individual actors perceive (and feel), judge, decide, act, and learn. Among the many possible results that could have been considered, we believe that those presented here—also due to their relative generality and ubiquity, much like the logic of appropriateness or the very concept of bounded rationality in its broadest definition—serve as cornerstones for a realistic description and a deeper understanding of both individual and, subsequently, aggregate behaviour and learning within contemporary capitalist economies.

Our somewhat radical suggestion is that evolutionary theories should make much greater and more systematic use of evidence from other cognitive and social sciences as building blocks for the hypotheses on cognition, learning, and behaviour that they adopt. We fully recognize that such a perspective almost inevitably requires abandoning any invariant axiomatics of decision and choice. However, there are many other fields from which a positive theory of agency and learning in

economics can draw, ranging from cognitive and social psychology to anthropology and the sociology of knowledge.

A final caveat is in order. As one moves downward through the levels and scales of analysis, phenomenological richness increases. Aware of this, the selection of empirical regularities considered at this very ground level has been guided by their relevance to the foundational understanding of behaviour and learning, precisely within complex evolving economies. Indeed, these micro-level findings from cognitive and social sciences are themselves distinctive of agents interacting within complex and constantly changing environments.

3.1 Cognitive categories and problem solving

An essential aspect of agency and learning concerns most often *cognition*, that is the process by which decision makers form and modify representations in order to make some sense of a reality which is generally too complex and uncertain to be fully understood. Hence, the necessity to acknowledge the existence (and persistence) of a systematic gap between the agents' cognitive abilities and "reality" (were there an omniscient observer able to fully grasp it). Such a gap can take at least two, often interrelated, forms [9]: *first*, a *knowledge gap*, involving incomplete, fuzzy, or simply wrong representations of the environment; and, *second*, a *problem-solving* gap between the complexity of the tasks agents face and their capabilities to accomplishing them.

Regarding both, evolutionary theories of agency and learning might significantly benefit from that branch of cognitive studies concerned with the nature and changes of *categories and mental models* (in different perspectives, cf. Johnson-Laird, 1983, 1993, 2006, 2010; Johnson-Laird *et al.*, 1999a; Holland *et al.* 1986; Lakoff, 1987; Margolis, 1987; Legrenzi *et al.*, 1993; Jones *et al.*, 2011; the focus on mental images in Kosslyn, 1980, 1983, 1994 and Kosslyn *et al.* 2003; the presentation of a few alternative theories in Mayer, 1992, and some relevant perspectives on the role of models in fundamental aspects of human reasoning in Goldvarg and Johnson-Laird, 2001; Johnson-Laird, 2001; Johnson-Laird *et al.*, 1999b; Markovits and Barrouillet, 2002, among many others).

It is crucial to note that, if one accepts any "mental model" view, learning (Wulff *et al*, 2018) cannot be reduced to information-acquisition (possibly *cum* Bayesian processing of it), but rather it is centred around the construction of new cognitive categories and "models of the world". In turn, robust evidence shows that cognitive categories are no clear-cut constructions with sharp boundaries and put together in fully consistent interpretative models. Rather, they seem to display (also in all our minds!) blurred contours, shaded by an intrinsic fuzziness, held around some cognitively guiding "prototypes", and organised together in ill-structured systems kept operational also via a lot of default hierarchies (cf. on all those points Tversky and Kahneman, 1982; Kahneman and Tversky, 1986; Einhorn and Hogarth, 1985; Holland *et al.*, 1986; Lakoff, 1987; Margolis, 1987; Griffin and Tversky, 1992; Marengo, 1996; Marengo and Tordjman, 1996; Legrenzi and Girotto, 1996).[10]

[9] Heiner (1983) introduces a similar concept which he calls the "C-D (competence-difficulty) gap". In his definition such a gap reflects the agent's imperfect capabilities to correctly process the available information and act reliably. Heiner's C-D gap does not properly belong to the realm of cognitive gaps, but it rather captures their behavioural consequences.

[10] "Prototypization" is easy to understand intuitively: you would give a sparrow rather than a penguin as an example of what a bird is... But with that it is also easier to understand the basic ambiguity of boarderliners, fuzziness and categorical attributions by default (how should one treat a duck-billed platypus? as a mammal? or should one create a separate category, that of ovoviviparous?). A discussion of these issues bearing on economic judgements and behaviours is in Tordjman (1998).

3.2 Framing and social embeddedness

Cognitive categories—it has been repeatedly shown—go together with various mechanisms of framing by which information is interpreted and also rendered operationally meaningful to the decision-makers (cf. Kahneman *et al.*, 1982; Borcherding *et al.*, 1990; March, 1994).

Frames appear to be indeed a ubiquitous feature of both decision-making and learning. What one understands is filtered by the cognitive categories that one holds, and the repertoires of elicited problem-solving skills depend on the ways the problem itself is framed. That is, framing effects occurs along all stages of the decision process—affecting representations, judgements and the selection of behaviours (cf. Kahneman *et al.*,1982; Tversky and Kahneman 1986; Kahneman, 2003, 2011 and, concerning the patterns of activation of experts' skills, Ericsson and Smith, 1991; Ericsson and Charness, 1994; Feltovich *et al.*, 2006).

As James March put it:

> Decisions are framed by beliefs that define the problem to be addressed, the information that is deemed to be relevant, and the dimensions that must be evaluated. Decision makers adopt paradigms to tell themselves what perspective to take on a problem, what questions should be asked, and what technologies should be used to ask the questions. Such frames focus attention and simplify analysis. They direct attention to different options and different preferences. A decision will be made in one way if it is framed as a problem of maintaining profits and in a different way if it is framed as a problem of maintaining market share. A situation will lead to different decisions if it is seen as being about "the value of innovation" rather than "the importance of not losing face".
>
> (March, 1994, p. 14)

Note that in this view, "frames" include a set of (non-necessarily consistent) beliefs over "what the problem is" and the goals that should be achieved in that case; cognitive categories deemed to be appropriate to the problem; and a related menu of behavioural repertoires.

Moreover, framing mechanisms appear at different levels of cognitive and behavioural observation: they do so in rather elementary acts of judgement and choice, but are also a general organizing principle of social experience and collective interactions (Bateson, 1972; Goffman, 1974).

One can also intuitively appreciate the links between framing processes and the social embeddedness of both cognition and action, a key aspect emphasized in much of the contemporary literature in social psychology (such as Smith and Semin, 2004, and has also been notably explored in the research tradition which refers to Bandura 1986, 2001, 2012).[11]

At the same time, but in the opposite direction, various types of frames operate within social cognition, shaping how individuals detect and react to the behaviour of other human agents. This process relies on either mentalized simulation or more fundamental mechanisms such as template matching and pattern recognition of social behaviours and roles (Goldman, 1999, 2006; Bermúdez, 2006).

Frames—in the broad definition given above—have long been recognized in the sociological and anthropological literature (whatever name is used to refer to them) as being grounded in the collective experience of the actors and in the history of the institutions in which agency is nested.[12]

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[11] On the notion of "social embeddedness" as from contemporary economic sociology, see Granovetter (1985) and several contributions in Smelser and Swedberg (1994) and (Collins, 2004). A discussion quite germane to the argument developed here is in Tordjman (1998).

[12] Within an enormous literature, just think of a good deal of the sociological tradition influenced by the works of Talcott Parson or of the classic Bourdieu (1977); in anthropology, among others, cf. the discussions of "embeddedness" by Karl Polanyi (1944/2001 and 1957) and Geertz (1963); see also Edgerton (1985).

Indeed, embeddedness seems to go a striking long way and affect even the understanding and use of cognitively basic categories such as that of causality and the very processes by which humans undertake basic operations such as inferences, generalizations, deductions, etc. (Luria, 1976; Lakoff, 1987, 2004).

Moreover, in the molding of agents' interpretations, motivations, and intentions, not only does being embedded in a socio-cultural setup play a role, but also being a node within a network of social interactions and relationships that actively intervene in the mental configuration of the node itself (the importance of relationships and their formative power in shaping various dimensions of individual cognition and agency was already identified by Malinowski, 1922. Later, in social anthropology, a more sociocentric approach, which highlights how social organization directly concepts and categories of thought, can be found in Leenhardt, 1947; Dumont, 1970; Geertz, 1973 and in many works by Strathern—among which Strathern (1995) additionally focuses on the connection between relationship and complexity. For a resolution into a continuum of the dichotomy individualism-sociocentrism regarding individual agency, see Carsten, 2004; Remotti, 2009).

We are therefore fully aware that cognition and agency may be imbued with a cultural dimension from their very origin[13] and that they may exhibit significant variations in different socio-cultural contexts. However, this phenomenological richness does not in any way preclude the objective of this paragraphs, which aims to outline some relevant and somehow universal building blocks of behaviours and learning. Rather, while we acknowledge the valuable contributions of field studies in exploring the heterogeneous local enactment of cognition and agency, we argue that, for the purposes of this work, it is essential to prioritize "invariant" (Simon, 1990) human patterns within contemporary capitalist economies. Consequently, we intend to draw upon workable generalizations from other disciplines regarding ubiquitous—or at least recurrent—individual regularities, as they manifest in the inherently complex and uncertain settings of evolving economic systems. In other words, one should focus on similarities rather than differences, using the mentioned stylized facts from cognitive and social sciences as building blocks for evolutionary theories of agency and learning in complex and evolving economies.

3.3 Heuristics in Judgement and Learning

Broadly defined, heuristics are methods, rules or criteria guiding e.g., representation, judgement or action—and include, primarily, simple rules-of-thumb.

Note that all these cognitive and behavioural regularities apply to both decisions (as taken once-and-for-all) *and learning processes* (for example, representativeness heuristics lead to learning patterns at odds with Bayesian predictions; and illusion of control is likely to entail information-censuring and escalating commitments in the face of unfavourable outcomes...).

It is impossible to provide here any thorough account of the findings in this area. Two classic references are Kahneman, Slovic and Tversky (1982), in a perspective which continues to use "Olympic" rationality as a kind of a yardstick of comparison, and Gigerenzer (2015) for the view that sees heuristics as a radical alternative to "rational decision making", whatever that means.

Even more radically, in the *homo heuristicus* view (e.g., Gigerenzer and Brighton, 2009), heuristics represent an alternative view of how "naturally reasonable" human beings (and maybe even primates!) typically behave.

More than that: it might well be that so-called "biases" emerging in relatively simple decision set-ups could be revealing clues about cognition and behaviours in all other genuinely evolutionary

[13] Regarding the thesis that emphasizes the "cultural nature" of human species (already present in *Homo habilis)*—rather than viewing humans as natural beings who acquired or produced culture at a later stage—and, more broadly, on the biotic relationship between nature and culture, the literature is vast. Among others, see Geertz (1979), Tomasello (1999), Ingold (2001), Klein (1989), Bonner (1980), and Descola (2013).

circumstances which are common to human decision makers (whether individuals or organizations): after all, pushing it to the extreme, the collective evolution of human cultures has not been drawn from repeated trials on lotteries but on quite diverse experiences having nonetheless *uniqueness* features in common, out of which our cognition and beliefs had to make some precarious sense. From the threats in the forest to deaths of the relatives, from unexpected kin's violence to the discovery of fire and microprocessors…[14].

We believe that it is precisely (and exclusively) this second positive interpretation of heuristics—the *homo heuristicus* view—that can serve as a central pillar for a positive theory of cognition and action, onr capable of shedding light on behaviour and learning in complex evolving economies. Therefore, we embrace the interpretation of heuristics that, from the original formulation of bounded rationality (Simon, 1955), has captured and inherited the commitment to study the natural dimension of the human mind and to adopt a view of human cognition and agency that reflects the condition of real agents.

Consequently, we opt for the research path that remains aligned with the authentic research spirit of Simon (1947), interpreting heuristics as simple and efficient rules encoded by evolutionary processes or acquired through learning, rather than as biases—deviations from rationality that often result in economic losses (Kahneman *et al*., 1982). This *fast and frugal* tradition, in fact, recognizes the constitutive role of the environment (Torgler *et al*., 2021) emphasized by Simon's investigation into human decision-making behaviour. On the one hand, he highlighted how the uncertainty of the environment itself, in its more or less substantial form (Dosi and Egidi, 1991)—a fundamental trait of complex evolving economies—hinders Olympic rationality. On the other hand, he asked how human beings actually make decisions in the daily "wild" environment (Spiliopoulos, 2020), adopting a naturalistic approach to human cognition (Viale, 2020).

Recognizing that this is a key to understanding, describing, and explaining behaviour and learning in complex evolving economies, we also embrace Simon's fundamental thesis that both cognitive limitations and the structures of the environment—together with the ways in which an organism handles these "ecological" features—are essential to understanding the heuristics involved in judgment and decision-making.

3.3.1 Adaptive Rationality

With the intent of capturing the original pragmatic orientation (Katsikopoulos, 2014) of Simon's epistemological stance to agency and cognition, we endorse the thesis that, before any further evaluation, human boundedness must be studied and framed, scientifically and conceptually, within the natural (and therefore social, cultural, and consequently economic) environment in which it emerged and in which it currently operates.

In accordance with Gigerenzer, Todd, and the Adaptive Behaviour and Cognition group research approach (Gigerenzer and Selten, 2001), we consider it essential to recognize the adaptive nature of human cognition and agency, and to reattribute apparent limitations to their original ecological function—repositioning the human mind within the surrounding context in which it is constitutively embedded. Consequently, we align with the *fast and frugal* interpretation of heuristic—as well as with the broader and fertile framework of *ecological/adaptive rationality* in which it is situated—closer to the one given by 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.

[14] One of the few exploratory attempts to positively account for "rational biases" as crucial clues on cognitive patterns in Margolis (1987). Totally sharing the idea that they should not be simply dismissed as pathologies (cf. Tordjman, 1998), in another work it is suggested that they could indeed provide a crucial *collective* evolutionary role, at least with regard to a particular one (i.e., overconfidence and illusion of control: Dosi and Lovallo (1997)).

Rather than mere descriptions of errant effects, we therefore embrace the conceptualization of heuristics as algorithmic models of decision-making included in the "adaptive toolbox" (Gigerenzer, 2001), shaped by neurobiological evolution, of simple strategies suitable for exploiting the informational structure of the natural and social environments. To that end, heuristics—among which the most fundamental may be the ancestral *satisficing* criterion identified by Simon (Loock and Hinnen, 2015)—have evolved with an algorithmic architecture[15] and consist of three building blocks: a search rule, a stopping rule, and a decision rule (Gigerenzer, 2021).

Parallel to—and consistent with—the ecological/adaptive foundation of a fundamentally pragmatic rationality, the biological-evolutionary perspective has been enriched by a revitalized importance attributed to the body, and it has converged towards an embedded and embodied synthesis on human cognition where bodily interaction with the environment molds the cognitive activity, the field of possible options and the value attributed to them (in different perspectives and research fields, cf. Gallese, 2007; Barsalou, 2008; Lakoff, 2012; Gallagher, 2014; Varela *et al.*, 2017; Gallese *et al.*, 2021; Damasio, 2021; Viale *et al.,* 2023; Basso and Herrmann-Pillath, 2024; and for an "enactive" extension Viale, 2023; inspired by the classic work on perception by Gibson, 1979).[16]

3.3.2 Less-is-More in Uncertain Worlds

In line with Simon's view, Gigerenzer and Brighton (2009) have demonstrated that heuristics are efficient cognitive processes capable of performing satisfactorily by ignoring certain information (here, we refer primarily to automatic processes, but also the conscious choice not to seek or use information, commonly referred to as *deliberate ignorance,* appears to be a widespread and recurring psychological trait in humans; in this regard see Hertwig and Engel, 2016).

Contrary to the widely held belief that reduced processing lowers accuracy, research on heuristics shows that, in contexts of particular uncertainty, using less information, computation, and time can, in fact, enhance accuracy.

Uncertainty is a multifaceted concept that, in decision-making, can involve various elements, including the outcomes of decisions, the range of available options, the relevant characteristics of alternatives, and even an individual's own preferences, whether present or anticipated (Viale, 2017). Unlike risk—technically defined as measurable uncertainty (Savage, 1954)—strong uncertainty (even in its weaker epistemological nuances), which characterizes the "large world" of human daily life, typically renders problems ill-defined. This means that "the goals are not definite; we don't know what counts as an alternative and how many alternatives there are [and] it's unclear what the consequences might be and how to estimate their probabilities and utilities" (Viale, 2017, p. 248).

In fact, strong uncertainty—which not only pervades everyday life plans "like organizing a picnic" (Savage, 1954, p. 16) but is most notably a fundamental intrinsic feature of complex evolving economies—entails genuine ignorance and the intrinsic inadequacy of economic agents' mental models to fully capture the complete structure of the environment (Dosi *et al*., 2020a).

Gigerenzer argues that while in the "small worlds" of calculable risk heuristics may be subject to the accuracy-effort trade-off attributed to them by the *heuristics and biases* tradition, it seems plausible that "under uncertainty, less-is-more effects exist" (2021, p. 3564). This feature has been observed in the functioning of heuristics under conditions of uncertainty, where the traditional trade-off is generally replaced by the bias-variance dilemma, which affects many predictive statistical and

[15] Note also that from a theoretical point of view, the algorithmic foundation of heuristics is not compatible with the dual-process theory of cognition (Wason and Evans, 1974) to which Kahneman (2011) refers. The naturalistic perspective that situates adaptive cognition and behaviour—and thus heuristics—within the evolutionary process that has shaped human beings adopts instead a holistic model of the mind (Viale, 2020).

[16] For a brilliant use of neurocognitive insights to simulate a multimodal behavioural agent to model social phenomena, see Epstein (2014).

algorithmic models. Because of this phenomenon, there exists a threshold where more is not better but harmful. Decomposing predictive error into its bias and variance components reveals that excessive effort to reduce one often exacerbate the other, ultimately preventing improvements in accuracy.

Finally, aligning with Simon and Newell's (1971) notion of heuristics as expedients that help reduce the time required to reach a solution, the ecological perspective on economic decision-making emphasizes that, when a heuristic's intrinsic bias is well-fitted to the task environment, heuristics can perform effectively and more frugally, relying on less information and computation.

3.4 Endogenous preferences

The just mentioned heuristics and behavioural patterns often entail preferences which are state-dependent. *Status quo* biases are a case to the point: the reference is not some invariant utility—however defined—but "... where I was, what I had, etc., at time *t* minus one...". In turn that of course is in open violation of any standard, utility-based, decision-theoretic approach, whereby preferences are supposed to be defined on levels and not history-dependent variations and, moreover, are supposed to change on a time scale that is significantly slower than decisions and random occurrences of "nature".

Moreover, it has been shown, the framing of the problem shapes revealed preferences (a huge literature in the field of marketing points in this direction, but particularly sharp experiments are in Kahneman *et al.*, 1991), and, much more generally, do authority relations (cf. Milgram, 1974).

Endogenous preference may be often driven by the attempts to reduce regret and cognitive dissonance (cf. Festinger, 1957): that is, citing a pop song from the 60's, "...if you cannot be with the one you love, love the one you are with...!".

And, finally, of course, endogeneity of preference is likely to stem from social imitation and other forms of social interactions, such as Veblenian "conspicuous consumption" and "snob effects", but this is a much more widespread phenomenon[17]of socio-economic systems.[18]

4. Toward an "evolutionary" view of agency and learning

As we see it, such an "evolutionary" view[19] of agency and learning, still to come, is going to embody the following "building blocks", namely:

- Cognitive foundations focused on the dynamics of *categories* and *mental models;*
- *Heuristics* as quite general processes for decision-making and learning;
- *Context-dependence*, and, relatedly, *social embeddedness* of both interpretative models and decision rules;
- *Endogeneity* of (possibly inconsistent) *goals* and *preferences;*
- Processes of *learning, adaptation,* and *discovery* apt to (imperfectly) guide, in turn, representations and behaviours especially in *ever-changing environments,* so that, even if "you

[17] For a more detailed discussion, see Chapters 7 and 8 in Dosi (2023).

[18] In economics, empirical studies of preference formation were a lively field of investigation in the 50's and 60's (cf. Katona, 1951 and 1968) but were pushed aside by a new generation of believers in expected utility theory. Among the discussions and formal models dealing with these issues in economics cf. March (1988), Akerlof and Dickens (1982), Kuran (1991) and Brock and Durlauf (2001).

[19] We call it an "evolutionary view" because it is consistent with the evolutionary research program as it is emerging in economics. Similar views, defined from the perspective of other disciplines, might well take different labels. For example, what we label here as "evolutionary" highly overlaps with the research programs on "adaptive learning" and "mental models" in cognitive psychology and artificial sciences.

cannot bathe twice in the same river", one still tries to develop some robust representations of the river itself and some swimming heuristics.

It is easy to understand the fundamental departures that this view entails *vis-à-vis* the canonical decision-theoretic one.

First, it abandons any "small world" assumption: in fact, it is centred on a sort of *open world* postulate (one tries to make sense and survive in a world where there are many more things between heaven and earth than in anybody's philosophy... and, thus, one has always to face surprises...).

The clear downside of this perspective is that, *in practice and in principle,* neither the agents we want to describe, nor the theorist might be able even to define what is a "rational" decision procedure, unless either is a God with an *infinitely* accurate knowledge of all possible histories. Note that this condition on infinitely perfect knowledge does not only apply to the case of genuinely evolutionary worlds: it holds also in all environments whose basic laws of motion are given and understood but exhibit non-linearities and sensitive dependence on initial conditions—such as chaotic dynamics (a few more remarks on this topic are in Dosi and Metcalfe, 1991, and the references therein).

Second, the evolutionary view, as we see it, is not committed even to any procedural consistency: rather than blackboxing the algorithms for cognition and action, it considers the understanding of their mistake-ridden development as a crucial analytical task.

Third, it implicitly acknowledges the failure—as a general *descriptive* theory—of the axiomatic route and undertakes the less elegant path of a *constructive theory*, almost inevitably tainted by phenomenological specifications and restrictions.

4.1 From the individual level to collective behaviours and learning

What has been said so far regarding cognition, judgement, etc. applies in principle also to all set-ups where individual agents may be assumed, at least as a first approximation, to act as insulated entities (notwithstanding, of course, the whole experience of socialization they carry with them). Other circumstances, however, are explicitly and immediately social: multiple-actor decision making, such as that required by "teams", economic organizations, and other institutions fall within this category (for a thorough discussion, cf. March, 1988, 1994).

Once more, it would be futile to try to review the enormous literature in the field. Let us just offer a few interpretative elements.

First, the evidence suggests that, if anything, collective decision making rather than curbing the judgmental "biases" mentioned earlier (say, via some equivalent of a "law of large numbers") tends, on the contrary, to reinforce them (March, 1994; Lovallo, 1996).

Second, the "opaqueness" of the relationship between beliefs, behaviours, and outcomes undermines the usefulness of representing multi-actor choice in terms of the canonical, linear sequence. Rather, the general case seems to fit quite well the observation of Purkitt and Dyson (1990), who—describing the decision process during the Cuban missile crisis—note the general lack of "explicit linkages between information, a sense of the problem and problem responses" (Purkitt and Dyson, 1990, p. 363).

On the contrary, the archetypical decision process and, dynamically, the archetypical learning process might fit quite well the *garbage can model* (Cohen *et al*., 1972). That is: in a garbage can process, it is assumed that there are no exogenous, time-dependent arrivals of choice opportunities, problems, solutions, and decision-makers. Problem, and solutions are attached to choices, and thus to each other, not because of any means–ends linkage but because of their temporal proximity. At the limit, for example, almost any solution can be associated to almost any problem—provided they are evoked at the same time (March, 1994, p. 200).

Third, multiple (and possibly conflicting) beliefs, goals, and identities are likely to entail systematic decision inconsistencies, while learning and adaptation in these circumstances may well path-dependently strengthen these inconsistencies themselves (March, 1988, 1994). All this applies, even more so, in the presence of multiple objectives of individual organizational members and of the organization as a whole (a related and more detailed discussion in Dosi, 1995).

A similar style of representation and interpretation should apply to the emergence and self-maintenance of organizational forms and institutions: they are partly the result of directed (purposeful) actions by the agents but also partly the unintentional outcome of collective interactions and the interplay of agents learning.

Consequently, to answer the question of what remains of individual behaviour when we observe and investigate the emergent properties of collective entities, we maintain that—since these belong to a different and "higher" level of analysis—it is useful, for the interested social scientist, to approach such phenomena with a conceptual apparatus that does not aim to derive (or reduce) them solely to the intentionality of any particular individual. When addressing the behaviour and learning of a collective agent such as an organization, we therefore conceive these phenomena more appropriately as properties that emerge at the inherently aggregate epistemological level *organization.*[20]

These properties, which often persist over time, phenomenologically arise from the interplay of multiple interdependent and co-evolving elements, some of the most relevant of which are presented in the following paragraphs.[21]

To conclude, the collective behaviours and learning processes—echoing Anderson's (1972) tenet, are best captured by conceptualizing them within a framework specific to the organizational order "firm"—a wholly new and distinct level from that of individual human beings. This perspective acknowledges that organizational agency and learning are not simply "more" but also qualitatively "different" (even in terms of temporal scale) from what could be understood by focusing solely on insulated "parts" and, eventually, the simple sum of their actions and interactions.[22]

5. Corporate Organizations

The levels of generality of most of what said so far—on decision-making, knowledge, learning processes, etc.—place the argument very near to major foundational issues on cognition and agency in general and in evolutionary environments in particular. However, a good deal of (highly complementary) efforts by evolutionary-inclined scholars has been recently devoted to empirically grounded "appreciative" theories, to use the definition of Nelson and Winter (1982), in particular in the fields of *technological and organizational* learning. The architecture of economic reality is indeed composed of complex social systems (Simon, 1996), among which firms represent one of the most relevant examples. Consequently, in addition to all the aspects previously identified concerning learning and the cognition and agency of individual economic agents, it is necessary to identify which other empirically observed elements, specific to the aggregate level of analysis of organizations, are essential for describing their behaviours and processes, with learning being foremost among them.

In modern economies, as discussed in Dosi (2023), firms are major, albeit by no means unique, *repositories of knowledge*. 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 good extent into the operating procedures ("the routines")

[20] For further clarification regarding the transition we make in this article from the individual to the collective level of analysis—contextualized within the general architecture of the work and in relation to its overall purpose—see also the introductory paragraph.

[21] We do not address organizational forms here—despite their role as fundamental structural aspects—but for a presentation of the archetypes that have emerged in the history of *modern* capitalism, see Chapter 4 of Dosi (2023).

[22] Indeed, interaction itself lies at the foundation of knowledge, which, by its very nature, immediately takes on a collective dimension—such as at the organizational level—and serves as a fundamental driver of emergent phenomena.

and the higher-level rules (concerning e.g., "what to do when something goes wrong", or "how to change lower-level routines") that firms enact while handling their problem-solving tasks in the domains of production, research, marketing, etc.

Dynamically, technological knowledge is modified and augmented partly within individual firms, and partly through the interaction with other firms (competitors, users, suppliers, etc.) and other institutions (universities, technical societies, etc.). In these domains, growing literature on organizational capabilities and competencies has begun to explore the links between specific ensembles of organizational routines, types of organizational knowledge and corporate strategies.

The knowledge of an organization regards, *first*, its cognitive memory—the structure of beliefs, interpretative frameworks, codes, cultures by which the organization interprets the state of the environment and its own "internal states" (Levitt and March, 1988). *Second*, organizational knowledge includes routines—comprising standard operating procedures, rules, and other patterned actions: call that the operational memory of the organization. In short, the two types of memory concern the organizational capabilities to "understand" the characteristics of the environment, on one hand, and to coordinate particular sequences of actions across different decision units and individuals, on the other.

Agents are always capable of discovering new technologies, new ways of organizing, and new behavioural patterns. In fact, in many respects, a major frontier in the analysis of business organizations involves the exploration of the outcomes of the mappings between types of knowledge, memory characteristics, organizational architectures, and patterns of environmental change, as well as the identification of the drives that generate differential growth (and possibly also differential survival probabilities) of different entities that serve as the "carriers" of diverse technologies, routines, strategies, etc.

5.1 Agency and Learning: conceptualizing firms as collective problem-solving entities

Just as a selection criterion was adopted to address the phenomenological richness inherent to the individual level of analysis, in these paragraphs we similarly present certain distinctive features of firms that are crucial for understanding and describing organizational behaviours and learning in complex evolving environments.[23]

To proceed meaningfully along this path—from individual-level analysis toward a positive theory of agency and learning of (and within) firms—we find it particularly valuable to draw on the tradition that conceptualizes organizations as *behavioural entities* in their own right, whose persistence, emergent agency and learning patterns certainly depend also on what the members of the organization do and learn but cannot at all be reduced to this dimension. In this regard, organizational behaviours and learning are understood as social phenomena that cannot simply be collapsed into the individual-scale dynamics (Marengo, 1996), even though such lower-level human features naturally constitute a precondition for the overall system's agency and learning capacity.

In Dosi (1995) and Dosi *et al*., (2020b), we develop this argument further and suggest that, for many analytical purposes, institutions—of which formal organizations are a subset—rather than individual "rationality" and preferences, ought to be considered as the primitives of the analysis. (For more precise definitions and discussions, see the mentioned Dosi *et al*., 2020b, and Dosi, 2023).

[23] These characteristics have been selected as they allow for a clearer specification of firm-level agency and learning by identifying the elements most pertinent to explaining the meso- and macro-level stylized facts mentioned in the introduction (which will not be further addressed here; see Dosi, 2023, for more details). Ultimately, it is these stylized facts that guide the restrictions on what should be considered at various levels of description and formalization, progressively descending from these facts to the individual, microfoundational level through a well-calibrated selection of the most relevant scientific results for the explanation of the higher phenomena under investigation.

Thus, it is crucial to advance in the study of the properties of economic organizations seen as *problem-solving entities*. A promising approach is to represent them in terms of explicit sequences of activities and procedures embedded within specific organizational arrangements that define "who does what," "who sends which signal to whom," and "who does what and with what consequences".

5.2 Rules and organizational routines

More generally, the issue of *organizational learning* involves the understanding of the processes by which organizational *rules* and *action patterns*[24] change over time. Here, just note that the relevant evidence coming from organizational studies points at organizations as *rather inertial behavioural entities* which nonetheless are able to (path-dependently) change either under the pressures of external adversities and internal conflicts, together possibly with the drive to exploit untapped opportunities.

Note that, in the evolutionary[25] theory, coordination is mainly achieved through routines (Nelson and Winter, 1982; Cohen *et al*., 1996), which in this sense have a similar function to Aoki's conventions, though the latter are equilibria of repeated games, while routines are patterns of behaviour inherited from past experience without any "equilibrium" connotation. These results are broadly along the same lines as the evolutionary theory of routines and their double nature of "cognitive" and "political" devices but provide a deeper view on the motivational aspect of organizations.

In a very broad sense, the concept of routines[26] refers sometimes to simple decision rules which require low levels of information processing (rules of thumb), but also, more often, to complex, automatic behaviours which involve high levels of repetitive information processing (Cohen *et al.*, 1996).

Organizational routines represent the *trait d'union* between technology and business organizations. In this perspective, therefore, there are no optimal configurations of organizational practices that lead to maximizing performance metrics (Dosi and Marengo, 2015). Firms – and more in general all types of organizations – must be understood, to repeat, as behavioural entities, inertial over time and tolerant of errors (Simon, 1991).

5.3 Competencies and Capabilities

It is familiar enough that business firms and other organizations "know how to do things"—things like building automobiles or computers or flying us from one continent to another. Our focus here is on the particular forms of organizational knowledge that account for the organization's ability to perform and extend its characteristic "output" actions—particularly, the creation of a tangible product or the provision of a service, and the development of new products and services.

We have already presented the view of the firms as *behavioural entities*, largely characterized by routinized patterns of action, which, in the longer term, are modified by more explicit "strategic" orientations. In turn, organizational routines and the capabilities emerging from them represent, to a large extent, the procedural counterpart of knowledge and its dynamics over time.

In this respect, possibly one of the most exciting and still ongoing intellectual enterprises of the last two decades has been the cross-fertilization between the evolutionary research program, largely evolutionary-inspired studies on technological innovation, and an emerging competence/capability-based theory of the firm, with complementary roots tracing back to the pioneering organizational

[24] Note that the two might not correspond at all, if by "rules" one means the explicitly stated operating procedures of organization, and "action patterns" are what actually members of the organization do...
[25] Discussion of routines as foundational behavioural assumptions of evolutionary models in Nelson and Winter (1982).
[26] The literature on routines is vast and articulated; for a more extensive discussion, see Dosi (2023) and the references therein.

studies of March, Simon, and their colleagues (Simon, 1957; March and Simon, 1958; March, 1988; Cyert and March, 1992; Augier and March, 2000, 2002).

Closely complementing analyses of innovative activities—focusing on the dynamics of knowledge, artifact characteristics, and input coefficients—organizational analyses have begun addressing the behavioural meaning of statements such as *"firm X is good at doing Y and Z…"*. In this context, a key question arises: what are the mechanisms that govern how organizational knowledge is acquired, maintained, and sometimes lost?

Organizational knowledge is in fact a fundamental link between the social pool of knowledge, skills, opportunities for discoveries, on the one hand, and the micro efforts aimed at their *actual* exploration, on the other. Distinctive organizational capabilities bear their importance also in that they persistently shape the destiny of individual firms—in terms of, for example, profitability, growth, probability of survival. Equally important, their distributions across firms shape the patterns of change of broader aggregates such as particular sectors and whole countries.

Organizational knowledge is a fundamental link between some *collective pool of knowledge/ skills/practices, on the one hand, and the rates, directions and economic effectiveness of this exploration/development/exploitation*, on the other.

Firms, in their hierarchical structure and functional division, are the locus of continuous and evolving learning, and their performance is driven by highly idiosyncratic technological and organizational capabilities grafted into their *procedural knowledge*—who does this, who sends the signal to whom, what should be done in case of errors.

In a first instance, we identify the term "organization competencies or capabilities" with the know-how that enables organizations to perform these sorts of activities.[27]

In line with Helfat and Winter (2011), let us refine the definition of what an organizational capability is:

- the possession of a specific capability requires that an organization or its constituent parts have the capacity to perform a particular activity in a reliable and at least minimally satisfactory manner;
- a capability has an intended and specific purpose, for example, the capability of building a car;
- a capability, differently from an ad hoc activity, which does not reflect predicted or patterned behaviours, enables repeated and reliable performance of the underlying procedure.

Capabilities involve organized activity, and the exercise of capability is typically repetitious in substantial part. Routines, as defined above, are the building blocks of capabilities with a repetitive and context-dependent nature—although they are not the *only* building blocks of capabilities. Individual skills, in turn, *might be* among the building blocks of organizational routines. Conversely, we shall call *organizational competencies* those shared pieces of knowledge and routines concerning the governance of coordination and social interactions within the organization and with outside entities (customers, suppliers, etc.), i.e., "how to handle people".

The literature further distinguishes between ordinary capabilities, roughly measuring the ability to do "business as usual", and dynamic capabilities, broadly meant as the ability to fruitfully alter precisely the usual way of proceeding (Teece et *al.*, 1997; Winter, 2003).

Four aspects are fundamental in the appreciation of organizational capabilities.

First, in a changing and evolving world, the distinction between the two types of capabilities is inevitably blurred, and, if taken too far, might well be interpretatively misleading. *Second*, both types

[27] For an essential bibliography on routines and capabilities, see Box 4.4 in Dosi, 2023.

do belong to the "quasi-genetic traits" of the organization, are relatively sticky and path-dependent, and in the short-term, only limitedly subject to the discretion of strategic management (see Pisano, 2017, for a discussion on the thorny issue of managerial discretion with respect to organizational capabilities). Third, as emphasized by Helfat and Winter (2011), capabilities are a matter of degree, ranging from minimally satisfactory to, say, exceptional (indeed, a notion quite natural among human beings, except economic theorists!). Fourth, capabilities essentially have a procedural nature: they are the collective organizational equivalent of "playing a violin in an orchestra well". In that, they are essentially an attribute of procedures, very different both from strategies and from "endowments", however defined.

A fundamental challenge in this research domain concerns its empirical counterparts. In this regard, one of the first attempts to identify organizational capabilities through data on Italian firms is the work of Costa *et al.* (2023) which, by operationalizing the notion of organizational capabilities, provides new evidence on the relationship between capabilities and economic performance.[28]

5.3.1 Individual Skills and Collective Competencies/Capabilities

Fundamental questions in the interpretation of the nature of organizational competencies/capabilities concern—as already mentioned—*first,* the *loci* where they reside, and, *second*, the extent to which they are *additive* in the skills and knowledge of organizational members.

In order to highlight some major underlying issues, let us dramatize two alternative views. The first archetype, which shall call the *modular view,* holds that "organizational knowledge" is primarily a shorthand for the knowledge of the individuals belonging to the organization. By the same token, in this perspective, strong warnings come—as H. Simon puts it—against "reifying the organization and talking about it as "knowing" something or "learning" something. [Rather], it is usually important to specify where in the organization particular knowledge is stored and who has learned it" (Simon, 1991).

Here, one of course is far from denying the importance of individual skills as constituents of the broader organizational competencies/capabilities. However, largely in tune with an alternative *collective view* of organizational knowledge, let us suggest that competencies have indeed a dimension which is *not* easily reducible to those of the individual organizational members: "it is firms, not people that work in firms, that know how to make gasoline, automobiles and computers" (Winter, 1982); and, dynamically, organizational learning is a social phenomenon and cannot be reduced to individual learning processes of the members of the organization (more in Marengo, 1996).

To repeat, organizational knowledge is not only incorporated into the heads of organizational members but also into a) a set of routines, other organizational practices and shared representations, and b) a set of material artifacts which shape intra-organizational relations and individual behaviours (again, more in Cohen *et al.*, 1996).

5.4 Cognitive and operational memory

The existence and importance of organizational memory[29] is associated with the very ability of organizations to interpret their environment, learn how to solve operational problems and, by doing that, build constructs of knowledge that can be stored and reused (Argote and Ingram, 2000; Kaplan and Tripsas, 2008).

[28] This promising approach consists in the systematic mapping of organizational structures, routines, and heuristics into various indicators (primarily labour productivity), identifying the properties of different combinations of complementary practices.

[29] For an extensive discussion of the topic, see Dosi *et al.* (2017).

The nature and dynamics of organizational memory is, indeed, an essential ingredient of organizational capabilities that determine strategic choices in different competitive environments. The notion of organizational memory stands for an elusive albeit crucial feature of the organizational reproduction of knowledge as distinct from the memory of individuals, namely the ability of organizations to elicit stored information from an organization's history that can be retrieved to bear on present decisions (Walsh and Ungson, 1991). The property of memory of being "organizational" means that, *first*, it may well be distributed within the organization in ways such that no individual agent or subunit embodies the full representation, or the full behavioural repertoires, contained in the memory itself. *Second*, the organizational character of the memory also implies that it is resilient to environmental shocks as well as to the replacement of individual members of the organization.

Organizations "remember" because they entail explicit norms and, together, more tacit practices addressed to collectively solve practical and cognitive problems, ranging from, say, the production of a car, all the way to, e.g. the identification of a malaria-treating molecule. This is another way of saying that organizations learn, store, elicit and modify over time routines and other "quasi-genetic action patterns" (Cohen *et al.*, 1996).

Organizational memory concerns, *first*, the structure of beliefs, interpretative frameworks, codes, cultures by which the organization interprets the state of the environment and its own "internal states" (Levitt and March, 1988): in brief, call all this the *cognitive memory* of the organization. *Second*, organizational memory includes routines, comprising standard operating procedures, rules and other patterned actions: call this the *operational memory* of the organization. In short, the two types of memory concern the organizational capabilities to "understand" the characteristics of the environment, on the one hand, and to coordinate particular sequences of actions on the other.

As already mentioned, one side of the story is, in a broad sense, *cognitive*. The view of organizations as fragmented and multidimensional interpretation systems is grounded on the importance of collective information-processing mechanisms that yield shared understandings (Daft and Weick, 1984), or "cognitive theories" (Argyris and Schon, 1978), of the environment in which they operate, and that assist organizations to bear uncertainty, besides, as we shall see, manage environmental and problem-solving complexity. If one subscribes to the notion that organizational learning is a process of refinement of shared cognitive frames involving action-outcome relationships (Duncan and Weiss, 1979), and that this knowledge is retained—at least for some time—and can be recalled upon necessity, this is like saying that organizational learning is in fact the process of building an organizational memory. This cognitive part of the memory is made of "mental artifacts" embodying shared beliefs, interpretative frameworks, codes and cultures by which the organization interprets the state of the environment and its own "internal states" (Levitt and March, 1988).

Together, there is an *operational* side to the organizational memory involving the coupling between stimuli (events and signals, both external and internal ones) with responses (actions), making up a set of rules that remain available to guide the orientation of the organization and execute its operations. In this domain the memory largely relates to the ensemble of organizational routines—patterned actions that are employed as responses to environmental or internal stimuli, possibly filtered and elaborated via the elements of cognitive memory (much more on routines in Nelson and Winter, 1982; Cohen *et al.*, 1996; Becker *et al.*, 2005; Becker, 2005; and the literature reviewed in Dosi, 2023). As Cohen and Bacdayan (1994) put it, this procedural side is the "memory of how things are done", bearing a close resemblance with individual skills and habits, often with relatively automatic and unarticulated features (p. 554).

Cognitive and operational memories entail an "*if...then*" structure. Signals from the environment, as well as from other parts of the organization, elicit particular cognitive responses, conditional upon the "collective mental models" that the organization holds, which are in turn conditional upon the architecture of its cognitive memory.

Both cognitive models and operational repertoires are the outcomes of learning processes and evolve over time in response to experimentation and feedbacks from the environment. Memory may

crystallize and reproduce the advantages from learning about "good representations" and "good routines" but may also entail "competence traps" (Levinthal and March, 1993), harmful in changing environments.

5.5 Governance and Power

The relationship between knowledge and power, qualitatively at a core of a good deal of modern social sciences, has been almost entirely neglected by most formalizations. We can only mention a few initial attempts of ours (Marengo and Pasquali, 2012; Dosi and Marengo, 2015; Dosi *et al*., 2021). The term corporate governance refers to "the exercise of authority, direction and control [and, *also*, we add] to constrain and shape the *ex-post* bargaining over the quasi rents generated by the firm" (Zingales, 1998) and acquires some meaning only if we get out of the self-governing competitive market model.

The various approaches to this problem are very much embedded into the answers that different theories give to the basic question of what a firm is and what it does. In a view *à la* Alchian and Demsetz corporate governance is entirely reduced to contract governance, whereas in a view *à la* Grossman and Hart the allocation of ownership becomes the key issue.

What are the implications for governance of the evolutionary answer to the basic question? Are there evolutionary propositions concerning ownership structure and the allocation of authority, direction, control and power which can be derived from the evolutionary approach to the firm as locus of productive knowledge? Some work has already been done (see for instance Coriat and Dosi, 1998; Dosi and Marengo 2015; Dosi *et al*., 2021), but strong theorizing is still largely incomplete.

The problem-solving activities of the firm, to recall, can be conceived as combinations of physical and cognitive acts, within a procedure, leading to the achievement of a specific outcome. Its internal organization determines the distribution of the informational inputs across specific task units and, as such, the division of the cognitive labour. The correlated organizational notion is that firms possess the specific problem-solving competencies associated with their own operational procedures and routines, in turn embedded into the patterns of intra-organizational division of labour and assignments of decision entitlements.

An essential, although not unique, feature of organizations is their *authoritative structure*: indeed, authority relations are inherently different from exchange relations *and power must be considered an autonomous interpretative dimension*.

First, power entails the ability of some agent (the ruler, the authority) to determine the set of actions available to the other agents (the ruled).

Second, it involves the possibility of the authority to veto the decisions or intentions of the ruled ones.

Third, power relates to the ability of the authority to influence or command the choice within the allowed choice set (i.e., the span of control of the "ruled"), according to the deliberations of the ruler himself. Here, in these respects, the units of analysis are the dimensionality and boundaries of the choice sets and the mechanisms by which authority is enforced.

Fourth, the most subtle exercise of power concerns the influence of the authority upon the preferences of the ruled themselves, so that, in Max Weber's words, the conduct of the ruled is such that it is "as if the rules had made the content of the command the maxim of their conduct for its own sake" (Weber, 1978, p. 946). In this respect, ethics and codes of conducts, and even corporative behaviours are as such that the ruled is attached to the organization independently or without explicitly recognizing its authoritative role, or alternatively, perfectly aligning its interests with those one of the organizations.

Obedience, docility, identification in the role and in the organization are central elements of such processes of adaptive learning and coordination.

Docility offers the inclination to "depend on suggestions, recommendation, persuasion and information obtained through social channels as a major basis for choice" (Simon, 1993, p.156). And, emphatically, such inputs are not inputs to an inferential (let alone Bayesian) decision process. Both cognitive frames and preferences are endogenous to the very process of social adaptation and social learning. It is crucial to note that the social endogeneity of identity building is exactly the opposite to any type of decision-theoretic model: one learns socially not only what one can do, but, more fundamentally, what one wants, the very interpretation of the natural and social environment one lives in, and, ultimately, the very self-perception and identity of the agents.

In the evolutionary theory, the existence of mechanisms such as career paths and evaluation systems are *in primis* central in workers' identification in the organization and ought to be ultimately seen as the successful expression of power, given the hierarchical authority-ridden nature of the firm. Indeed, the most subtle exercise of power concerns the influence of managerial authority on attitudes and behaviours. The alignment of workers' and managers' objectives is a crucial element for the development of adaptive learning and coordination (Milgram,1974). Therefore, the implementation of mechanisms to reward or punish appropriate or inappropriate behaviour fosters not only what one *can do*, but more importantly, what *one wants*, corresponding to self-perception and identity of agents.

Finally, it is important to stress how this framework departs from the standard neoclassical approach to knowledge, delegation and decision rights. A basic tenet of this approach is co-location of decision rights and knowledge/information (Hayek, 1945; Jensen and Meckling, 1992) to maximize organizational efficiency (possibly net of agency costs). In our approach the principle of co-location is usually superseded by a sort of "divide and conquer principle" whereby the principal partitions decision rights more than optimally in order to increase control and power (Marengo and Pasquali, 2012). The outcome is a fragmentation of tasks and decision rights[30] well beyond the efficient level required by the underlying division of knowledge.

5.6 Heuristics and organizational decision-making

We have argued above that the internal working of organizations fundamentally rests on organizational routines. But what about major "strategic" decisions, regarding, among others, decision variables like quantities, prices, desired production, physical investments and R&D, hiring and firing?[31]

Let us start from what firms do *not* do.

As it is well known, the standard decision-theoretic models and, even more so, game-theoretic ones depict economic agency as a problem of choice where rational actors select, among a set of alternative courses of action, the one that will produce, in their expectation, the maximum outcome as measured against some profitability yardstick. In that, agents are postulated to know the entire set of possible events of "nature", all possible actions that are open to them—*all of them*—and all notional outcomes of the mapping between actions and events – or, at least, come to know them after some learning process.

[30] The tension between the distribution of knowledge and the distribution of power is raised in Chapter 4 of Dosi (2023).
[31] Regarding the interaction between the cognitive dimension and other aspects of the decision-making process, as well as its impact on firms' performance, we refer to the extensive discussion in the sections *Cognition and Representations*, *Divisions of Cognitive Labour and Problem Decomposition*, *The Role of Mental Representations, Conflict and Power* in Chapter 5 of Dosi (2023), where significant results obtained through formal models are reported.
For the contextualization of mental models within organizational decision-making, for example, see Gary and Wood (2011) and Gary *et al.* (2012), while, for "frames", Cornelissen and Werner (2014). Regarding the interaction between cognitive and social architecture in a more general context of corporate problem-solving, see Marengo *et al.* (2000).

Clearly, these are quite demanding assumptions on knowledge embodied in, or accessible to, the agents—which hardly apply to complex and changing environments. In fact, they cannot apply, almost by definition, in all environments where innovations of some kind can occur—irrespective of whether they relate to technologies, behavioural repertoires or organizational arrangements. If an innovation truly is an innovation, it could not have been in the set of events that all agents were able to contemplate before the innovation actually occurred…
Moreover, equally demanding are the implicit assumptions concerning the *procedural rationality* involved in the decision process. As a paradigmatic illustration, take the usual decision-theoretic sequence leading from (1) representation/"understanding" of the environment (conditional on whatever "information" is available) to (2) formation of expectations on tomorrow's state-of the-world, (3) evaluation/judgment, (4) choice, (5) actions and—ultimately—(6) consequences—determined, for example, by the stochastic pairing of actions and "events of nature" and/or actions by other agents.

There are some rather compelling reasons why these assumptions may, in fact, be a misleading starting point for any positive theory of organizational behaviour and learning.

But then what do agents (firms) actually do?

Modern firms—fundamental parts of complex evolving economies—have no alternative but to exist, operate, and survive in environments that change over time in ways that cannot be predicted in any detail. Technological advances are one of the primary forces causing permanent uncertainty, but also other causes concern the evolution of markets and competition regardless of whether these are associated with technological advance. That is, to recall, Knightian uncertainty obtains, both of the "substantive" and the "procedural" kinds. In these circumstances there is no way that a truly optimal policy can be even defined (among other things the choice set is not well specified), much less achieved.

It is crucial to emphasize that in complex evolving worlds, *even the analyst*, as well as any agent with the same knowledge of the analyst, would not do any better than the heuristic agent. Even in a stationary world, forming unbiased and accurate (low variance) estimates is difficult. These well-known problems are exacerbated by the intrinsic non-stationarity and non-linearity of the world as a whole, and especially in environments with complex interactions such as those explored in Dosi *et al.* (2020c). We are not able to dissect non-linear deterministic and possibly chaotic processes versus the seemingly stochastic components.

In the view presented here, the very nature of the economy implies that the world is too complex, and is changing too much, to be able to learn its fine structure, let alone its parameters. In these cases, no accuracy/efforts trade-offs in information gathering/complexity of forecasting appear: heuristics outperform more sophisticated forms of learning in forecasting because their forecast, while perhaps "biased" as compared to those which an omniscient Laplacian God would make, nonetheless have a lower variance than those which finite agents could make using seemingly sophisticated econometrics, even attempting to account for structural breaks.[32] In this world, it might be expected that "naturally rational" agents would adopt some heuristics in forming expectations and as the basis of decision making. Understanding the heuristics that agents use, and the systemic properties of economies with interacting agents using such heuristics in the presence of deep uncertainty then provides an alternative research agenda to that which has dominated both micro and macroeconomics at least over the past forty years.

5.6.1 Organizational "strategic" heuristics

It is typically managers and corporate decision-makers who, more than other members of the organization, embody the decisions of the economic agent "firm". And it is managers that routinely

[32] Formal details can be found in Dosi *et al.* (2020c)

rely on heuristics while constantly operate under radical uncertainty, which arises from the complexity of the problems they must solve and the unpredictability of a changing economic environment (Dosi, 2023).

At this point, however, a clarification appears to be necessary.

Given the evident overlap, in many circumstances, between the agency of certain individual decision-makers and the agency of the firm as a whole, the heuristics adopted by managers are therefore presumed to play a central—and direct—role in shaping the heuristics expressed by the organizations which populates complex evolving economies.

At the same time, however, within our conceptual and analytical framework, when referring to aggregated behaviours and processes, we reject the misleading hypothesis of isomorphism and maintain that, from an epistemological perspective, these cannot simply be reduced to identical dynamics of any single component of the system under investigation.

This implies that the heuristics embraced by an organization cannot be comprehensively understood through an exclusive focus on the heuristic decision-making of corporate managers. In fact, not only do many other aspects intrinsic to the organizational dimension of the firm bear upon the shaping the heuristics adopted by the organization, but even when a single manager makes a strategic decision, the individual heuristic itself is embedded within and influenced by (among many other elements): the organizational rules that govern it and the routines within which it occurs; the firm's capabilities, memory, and knowledge, on which it is grounded and to which, in turn, participate; the cultural and power configurations in which it is situated; and the organizational hierarchy and structure within which it takes place.

We are confident that this awareness can serve as the first building block of a bridge between two different research domains on heuristics: heuristics studied by cognitive and evolutionary psychology, and heuristics as often depicted in managerial and organizational studies. These represent two distinct interpretative perspectives on tools which, in both cases, are practical shortcuts for making decisions in the pitch darkness of radical uncertainty. The (frequently blurred) boundaries and interrelations between these two views lie at the heart of a promising research agenda aimed at clarifying their connections (Loock and Hinnen, 2015).[33]

Indeed, while organizational heuristics likely have their roots in the simple decision rules individually adopted by decision-makers in the "wild" (Gigerenzer, Hertwig, and Pachur, 2011), they blend into the social dimension and, in combination with the operational nature of routines, emerge at an aggregate scale as collective organizational practices. In sum, they emerge as a genuinely organizational property.

It is at this higher level that heuristics often become indistinguishable from strategies, operating in various domains and along multiple directions. Strategies, in actual fact, live on the uncertain frontier between organizational path-dependencies and attempts of exploration of new courses of action (see Levinthal, 2021, and recall the "exploration" vs. "exploitation" tension as in March, 1991), with different degrees of success depending on the "dynamic capabilities "of the organizations themselves and its management in particular (on the notion, see Teece, Pisano and Shuen, 1997; Helfat *et al*., 2007; Pisano, 2017).

Let us then turn to examples of heuristics in different "strategic" domains.

[33] Another difference between the two approaches concerns the varying emphasis placed on the automatic versus the more reflective (or at least conscious) components in the use of a given heuristic, with the latter being more prominent in the organizational perspective.

Production and Investment Heuristics

Typically, firms producing not too customized goods under non-decreasing returns to scale plan their production (Q_j) according to adaptive demand expectations (D_j^e):

$$D_j^e(t) = f\Big(D_j(t-1), D_j(t-2), \dots, D_j(t-h)\Big), \tag{4.1}$$

where $D_j(t-1)$ is the demand actually faced by firm j at time $t-1$, $t-2$, …, $t-h$, with h a positive integer. The desired level of production (Q_j^d) depends on the expected demand as well as on the desired inventories (N_j^d) and the actual stock of inventories (N_j):

$$Q_j^d(t) = D_j^e(t) + N_j^d(t) - N_j(t-1) \tag{4.2}$$

with $N_j^d(t) = \iota D_j^e(t), \iota \in [0,1]$. The output of firms might be constrained by their capital stock (K_j). If the desired capital stock (K_j^d)—computed as a function of the desired level of production—is higher than the current capital stock, firms invest (EI_j^d) in order to expand their production capacity:[34]

$$EI_j^d(t) = K_j^d(t) - K_j(t). \tag{4.3}$$

Adaptive expectations might also entail some "macro" variable, such as "the state of the economy" or "the state of the industry":

$$D_j^{e(t)} = f\Big(D_j(t-1), D_j(t-2), D_j^e(t-1), Y(t-1)\Big), \tag{4.4}$$

where Y is the gross domestic product. Note that well in tune with the evidence on organizational behaviour, quantities and prices are not set simultaneously, but are subject to different heuristics of adjustment. Moreover, they typically adjust slowly and at discrete time, (below, we shall describe the dynamics of price adjustment).

However, the simplest heuristics often resembles a zero-parameter rule of the kind

$$D_{näive,j}^e(t) = D_j(t-1); \tag{4.5}$$

that is, *today is like yesterday*.[35]

Scrapping and Replacement

The capital stock of each firm is obviously composed of heterogenous vintages of machines with different productivity.

We define $\Xi_j(t)$ as the set of all vintages of machine-tools belonging to firm j at time t. Firms scrap machines following a *payback period* heuristic. It basically says: *we shall replace a piece of equipment if the cost savings on variable costs that we obtain on the new equipment pay back the cost of the new equipment itself in less than b periods of production*. Of course, technical change and equipment prices influence the replacement decisions,[36] as well as the "patience" of the firm (influencing the value of b).

[34] We assume that in any given period firm capital growth rates cannot exceed a fixed maximum threshold consistent with the maximum capital growth rates found in the empirical literature on firm investment patterns (e.g. Doms and Dunne, 1998).

[35] The use of heuristics in decision-making under uncertainty is largely documented in the psychology literature, see in particular applications to exchange rate forecasts by banks using an adaptive heuristic in Gigerenzer (2015) and other management and economic decisions in Luan, Reb, and Gigerenzer (2019) and Boneva *et al.* (2020). See also Dosi *et al.* (2020a) for a more general review on "boundedly rational" organizational behaviours.

[36] This in line with a large body of empirical analyses (e.g., Feldstein and Foot, 1971; Eisner, 1972; Goolsbee, 1998) showing that replacement investment is typically not proportional to the capital stock.

More specifically, firm *j* replaces machine $A_i^\tau \in \Xi_j(t)$ according to its technology obsolescence as well as the price of new machines:

$$RS_j(t) = \left\{A_i^\tau \in \Xi_j(t): \frac{p^*(t)}{c(A_{i,\tau},t) - c^*(t)} \leq b\right\}, \tag{4.6}$$

where p^* and c^* are the price and unit cost of production upon the new machines.

Investment in Research and Development

The typical heuristic on R&D Investment is of the kind

$$RD(t) = x \cdot S_j(t) \tag{4.7}$$

With S the sales of the firm *j* at time *t*, possibly with some inter-temporal smoothing. This finding is corroborated by ample organizational evidence[37] and also by econometrics as early as Griliches *et al*. (1987) who find that "the pattern of R&D investment within a firm is essentially a random walk with a relatively low error variance" (pp. 10-11) (that is, technically, very near reflecting barriers).

An obvious question concerns the determinants the value of x itself. In line with the argument of Chapter 3, we suggest that it is primarily determined by *sector-and technology-specific opportunities of innovation and modes of search,* and it is adaptively learned by each firm. So, for example, in, say, shoe making it is basically zero, while typically in pharmaceuticals it takes a two-digit value.

Granted that, why in the drug industry the Jones firm invest 15% of its sales while the Doe firm 18%?

The basic answer is that these values are the outcome of path-dependent adaptation to ever-changing innovative and competitive environments (the conversation of the author with an R&D manager reported in Box 4.5 of Dosi, 2023 is a good illustration of the point).

Are these the "optimal" values of *x*? Not in any meaningful sense. Indeed, not even the analyst, short of being the omniscient God, knows what they are. Their being just *satisficing*, however, always means that there is always a potential edge of improvement. And this is indeed the domain for the "meta-heuristics" of students of organizational behaviour, for strategic management consultants and for snake oil peddlers alike.

Pricing

In order to talk about pricing behaviour, we must start with reference to two fundamental institutional and technological conditions under which prices are set. They regard, *first*, the nature of the networks of interaction among sellers and buyers; and, *second*, the conditions under which the object of pricing is produced, if at all.

(i) *Type of network structure* (We discuss this at much greater length in Dosi, 2023), concerning:

  (a) seller-buyer relationships; and

  (b) seller-seller relationships (basically, the type of competitive interaction, if any);

(ii) *Degrees of reproducibility* at the time scale at which purchases occur:

  (a) *No reproducibility* at any time scale (e.g., Picasso paintings; a cabin, alone, on the Galapagos islands, that is, more generally, "positional goods" *à la* Hirsch, 1976);

[37] See Kay (1979) for a general discussion of the R&D budgeting heuristics, and Quinn (1959), Schmookler (1962, p. 213), Thomas (1963), Mansfield (1968), Allen (1970), McCosh and Kesztenbaum (1979), Freeman (1982), Brockhoff (1989), Brockhoff and Pearson (1998) and Hartmann, Myers and Rosenbloom (2006) for case-specific evidence. The dearth of recent contributions with respect to this evidence is a reflection of the approach in economic theorizing, deriving theoretical assumptions on firm behaviour from other theoretical assumptions, rather than from empirical evidence.

(b) Reproducible, under *roughly constant returns*, at a time scale similar or slower than the one at which purchases occur (from fish to vegetables to corn to oil to copper ... to *used* cars), often with lags in supply adjustments;

(c) Reproducible under *non-decreasing returns* at a time scale faster than purchases (from cars to TVs to airplanes...);

(d) "immaterial goods" with zero or almost zero marginal costs and infinitely reproducible (or infinitely expansible, cf. Quah, 2003)

Basically, modern capitalism has developed around markets of the types (ii)(b) and (ii)(c)—modern manufacture mostly under (ii)(c)—and possibly contemporary capitalism is heading toward (ii)(d).

A necessary premise to what will follow is the admission that the economic analysis of how markets works and how prices are set is in a dismal state. For sure we knew more about *actual* pricing behaviours—at least for commodities under (c)—half a century ago than we know now.[38]

In the momentous fight between marginalist pricing theory and reality, the former won, and evidence turned out to be discredited thereafter.[39]

Granted that, let us consider some archetypical heuristics under conditions of production (ii)(b) and (ii)(c).

Let us consider first the case discussed in Artinger and Gigerenzer (2016) and (2025) of pricing heuristics in used car sales.

> Pricing on the basis of an aspiration level heuristic (pioneered by Simon, 1955) where prices are adjusted in regular time intervals can be summarized by a three-parameter strategy:
>
> $$p(t) = \begin{cases} (1+\alpha)p_{g,min,t} & if t \leq \beta \\ (1+\alpha)p_{g,min,t}\gamma^{m-1} & if \beta < t < m\beta' \end{cases} \quad (4.8)$$
>
> where the price of a car $p(t)$ at time t is initially equal to the minimum price $p_{g,min,t}$ in a group of matching cars g multiplied by the firm's specific parameter for the initial price $\alpha \in [0;1]$. With $\alpha = 0$ the firm's price is the cheapest in the group of matching cars. This price is kept constant up to a time threshold β. If the car is not sold by time $t > \beta$, the firm changes the price by $\gamma \in [0, \infty]$. This process is repeated until the car stops being on offer, where $m \geq 1$ is the count of prices per car. The model assumes that there is a sequence of consumers that inspect the car. The car is sold to the first consumer whose willingness to pay r meets or exceeds the price $p(t), r \geq p(t)$. Note that the model requires relatively little information and does not make any assumptions about for instance the nature of customers or how precisely competitors respond.
>
> (Artinger and Gigerenzer, 2016, p. 6)

Consider now commodities reproducible under non-decreasing (often increasing) returns, i.e., most of industrial goods. Here the typical heuristic is of the kind

$$P_j(t) = UVC_j(t) \cdot \Big(1 + \mu_j(t)\Big) \quad (4.9)$$

[38] See for example Hall and Hitch (1939), Andrews (1949), Eiteman (1949), Lanzillotti (1958), Kaplan *et al.*, (1958).

[39] Fritz Machlup, as early as the 1950s, summarizes such epistemology with embarrassing clarity: "When there is an apparent conflict between observations and the theory they are supposed to test, the observations can usually be disqualified as of uncertain reliability; and where this will not do, the conflict can usually be reconciled by means of auxiliary hypotheses" (Machlup, 1952); see also Machlup (1946) and (1955). Of course, when such a view became dominant, collecting evidence became worthless or even frivolous, unless if meant to parametrize and verify the "auxiliary hypotheses", and this is basically what practitioners in all fields of applied microeconomics have done in the least three decades or so.

Where the unit price of firm j is a *mark-up* $\mu_j(t)$ over "normal" unit variable costs *UVC*, often calculated as made of unit intermediate inputs $INT_j(t)$ and unit labour costs, i.e., wages $w_j(t)$ divided by the labour productivity $\pi_j(t)$ of that firm j at t. That is,

$$P_j(t) = \left(INT_j(t) + \frac{w_j(t)}{\pi_j(t)}\right)\left(1 + \mu_j(t)\right) \tag{4.10}$$

An overwhelming, old and new, empirical evidence supports the spread of such a heuristic[40] (an incomplete list of pricing heuristics is in Box 4.6. of Dosi, 2023)

Note, in this respect, that heuristics which *prima facie* might not appear cost-plus might indeed be such with the *levels* of the mark-ups themselves influenced by market penetration strategies. This is the case of the pricing of new products, whereby—as shown in Dosi (1984) in the case of semiconductors—the costs over which the marking is applied may well take into account learning curve dynamics.

Of course, this is only the skeleton of heuristics, whose actual parametrization is influenced by the technological and competitive conditions of the industry and of firm j within it.

The *levels* of the mark-up $\mu_j(t)$ are likely to depend, among other factors, upon

(i) the capital intensity of the industry;

(ii) the barriers to entry into the industry itself;

(iii) the relative competitiveness of firm j *vis-à-vis* the leaders of the industry.

An interesting case of (iii)—illustrated empirically with reference to a supermarket—is the path-breaking study by Cyert and March (1963), where the firm has two explicit and possibly conflicting *objectives*, namely, first, *profit margins*, and second, *sales-volumes*. To them correspond two, *loosely connected*, heuristics:

a. *Mark-up pricing*—in their case, "divide unit costs by 0.6 (= one minus the mark-up) and move the result to the nearest $ .95"; while, if sales fall in the near past, as lower-level heuristic;

b. *Mark-down pricing*—roughly, take the outcome of (i) and lower it by a percentage depending on the success of mark-down heuristics in the same or similar products.

There are a few fundamental characteristics of the organizational "strategic" heuristics discussed so far.

First, they are *multiple* in the sense that they are addressing *co-existing operational objectives*, even when motivated by one simple highly general goal—i.e., "make as much money as possible". The example of margins vs. sales above is a major case to the point.

Second, they are likely to originate from different branches and "power units" within the very same organization, e.g., production, research, marketing, etc. The "compromises" among different heuristics have to be negotiated "politically". A far cry from a representation of any firm as a monad straightforwardly behaving as a "maximizer" of profits or sales (for an extensive critique of the motivational and cognitive assumptions underlying the standard theory of the firm, see Cyert and March, 1963; March and Simon, 1993).

Third, to repeat from above, these heuristics *do, and are meant to, neglect information*. Indeed, in Gigerenzer and Gaissmaier's (2011) definition a heuristic is "a strategy that *ignores* part of the information, with the goal of making decisions more quickly, frugally and/or accurately than more complex methods" (p. 454, italics added). Differently from more sophisticated behaviours, heuristics

[40] That goes from Hall and Hitch (1939) to Kaplan *et al.* (1958), all the way to Bonoma *et al.* (1988), Tellis (1986), Noble and Gruca (1999). For a critical discussion, see Lee (1994).

do not strongly rely on the specific fundamentals of the environment in which they emerge, and this *frugality* is precisely why they prove *robust* to changing environments.

Fourth, just for the former reason, they are *not* "boundedly rational" in the sense of the currently accepted notion of "*behavioural economics*"; they are not noisy or biased approximations of some "Olympic rationality" interpreted either as something to be achieved, possibly through learning, or as the benchmark against which actual expectations ought to be assessed out of the "wilderness of bounded rationality" (Sims, 1980). They should not be considered as a second-best approximation, based on a trade-off accuracy/effort in the presence of cognitive limitations and biases. On the contrary, the *less-is-more principle holds*, and "[we] can rely on heuristics because they are more accurate, not because they require less effort at the cost of some accuracy" (Gigerenzer and Brighton 2009, 135).

Fifth, heuristics are *largely unconditional* procedures. That of course does *not* mean that an organization does not observe state *variables* of the environment and does not take them into account for its own decisions. It means, however, 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 (more in the Appendix 4.A of Dosi, 2023).

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