Study of Organization sans Strategy: Structural Rationality

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Structural Rationality: Study of Organization sans Strategy

> [E]conomists see rationality in terms of the choices that people make. Other social scientists view rationality in terms of the processes. I call the rationality of economics substantive rationality and the rationality of psychology procedural rationality.
> Herbert A. Simon (*Challenge* 1986, p. 2)

Abstract

Deliberate human action receives the first priority in our attempts to understand social phenomena. Organization theory and strategy literature are no exceptions. Strategy as a purposive plan of action or path towards intended ends has been studied in the context of agents' cognition and rationality, subject to conditions in and interaction with structures of the implementation environment. Turning the focus from construction of strategy towards organization structures allows for the possibility that (1) aggregate-level outcomes with specific properties may emerge from structures through complex micro-level interactions among even non-strategic agents, and (2) these properties may exhibit some robustness to variations in individual behavior. Extending on the counterintuitively efficient performance of "zero-intelligence" agents in certain markets, we explore the implications of supplementing the well-established framework of substantive and procedural rationality with *structural* rationality. In its minimalist spirit, structural rationality uses neither intent, nor deliberate formation of strategy to arrive at the outcomes, and thus allows for differentiation among organizational outcomes arising from strategies and from structures.

Keywords: Organization strategy, complexity, structural rationality, zero-intelligence.

JEL Codes: L10, L22, L29.

1 Modeling Elements: Agents, Paths, and Outcomes

Most extant models of human action have three main components: agents, paths, and outcomes. Modelers characterize the properties of agents based on some notion of rationality and then construct a path, which leads the agent from an initial condition to a desired outcome. In Herbert Simon's terminology, optimizing agents are characterized by *substantive rationality* and they arrive at the optimum outcome logically constructed from initial assumptions. Characterized by *procedural* *rationality*, boundedly-rational agents attain near-optimum outcomes[1] through adaptive strategies, which leads them to (slightly) different outcomes along different paths. Substantively rational agents and their modelers use the same methods to construct the path to the optimum outcome. Modelers of boundedly rational agents differ from the modeled agent in that they too use instrumental logic to reconstruct the paths that are actually taken adaptively by the agents themselves. Though both kinds of modelers use partially overlapping tool-sets in their craft, procedural rationality approach takes empirical observations of paths taken by agents seriously, and tries to adjust the model of adaptive agents so their logical behavior corresponds to what is observed. In Simon's words:

> [In treating rationality,] other social sciences [not economics] are more concerned about studying the individual and social processes in which individuals decide and act on their decisions. They study empirically the origins of values and how and why values change as individuals move through time and gain new experience. Economic theorists assume givens, as if they were facts, whereas in other social sciences, the investigator tries to determine empirically the substance of those givens. *Other social sciences also try to determine the calculating strategies that individuals use in the reasoning process that leads to decisions and actions*: people have limited information and limited computational abilities with which to function in a complex real world. In psychology, at least, researchers also have to describe and explain how nonrational processes [such as] human emotions and sensory stimuli shape the individual's focus of attention, which in turn fixes those aspects of the decision-making process that economists typically assume as givens. In short, economists see rationality in terms of the choices that people make. Other social scientists view rationality in terms of the processes. I call the rationality of economics *substantive rationality* and the rationality of psychology *procedural rationality*. (*Challenge* 1986, p. 2: emphasis added).

Simon describes economists as not concerned with establishing the empirical basis for the substance of their assumed givens. A common practice in economics is to choose a set of givens from which it is mathematically tractable to derive an optimizing path—substantive rationality—for agents to follow that yields an optimum outcome (Simon 1978, Mousavi & Tideman 2019). Simon's work (1957; 1972) bridged the gap between human cognition and assumptions required for achieving substantively rational outcomes by introducing the concept of bounded rationality. It relaxed considerably the demands that substantive rationality places on agent cognition and showed that near-optimum outcomes can be achieved with less-than-perfect cognition[2]. His boundedly-rational agent has since been developed in many forms such as satisficer, heurist, maximiner, imitator, reciprocator (e.g., tit-for-tat), etc., and in all

[1] This raises the important question of which environments allow us to know the optimum. We shall defer addressing it until the final section of the chapter.
[2] In the absence of optimum, real people, as opposed to the substantively rational agent, are not paralyzed with no decision, they attain good-enough outcomes and move one; an empirical fact that when taken into account can also reduce demands on formalization.

cases the agent's path to the outcome is reconstructed logically from the respective specification of such an agent. That is, while substantive and procedural rationality offer different approaches to micro-level modeling of agents and outcomes, they share the same logical approach and an overlapping tool set to (re)constructing the path to outcomes from their respective assumptions (Mousavi & Garrison 2003). They also share their constructivist approach to rationality (Smith, 2008) by deriving the final outcomes' properties from individuals' behavior. It is central to our argument in the current article that this methodology has given rise to a paradigm in which goals and even intent are attributed to inanimate organizations; yet their attainment requires deliberately devised paths constructed by agents following logical strategies. Aggregation of micro-level models has shaped a sizable portion of literature on macro-level formalizations.

As an alternative approach to the above-mentioned goal-seeking paradigms for the study of macro-level phenomena, we propose the concept of *structural rationality. Under structural rationality,* macro-level outcomes are seen as emergent properties of a complex system, instead of being derived merely as aggregations of actions of individual agents. Meanwhile, the details of how elemental interactions shape and emerge are not the target of modelers in this approach; in most cases such derivations are not possible either. Complexity theory and emergence literature leapfrog the exercise of reconstructing the path from micro-level behavior to macro-level outcomes, keeping incentives and cognition of agents at a minimal level.

The concept of emergence in economics is traceable to Scottish Enlightenment thinkers, as in words of Adam Ferguson (1767, p. 187) spontaneous orders are "of human action, but not of human design," and to Hayek's analysis of sensory order with reference to the biology work of Bertalanfy (1933) and Woodger (1929):

> . . . The peculiar properties of the elementary neural events which are the terms of the mental order have nothing to do with that order itself. What we have called physical properties of those events are those properties which will appear if they are placed in a variety of experimental relations to different other kinds of events. The mental properties are those which they possess only as a part of the particular structure and which may be largely independent of the former. . . (Hayek 1952, p. 47).

Beyond the analysis of human mind, Hayek placed emergent information aggregative and social coordination properties of markets at the center of his understanding of prices arising in spontaneous social and economic order (Lewis 2016, see also Hayek 1945, and for a contemporary account with similar thrust see Smith 2008)

When Gode and Sunder (1993) discovered the allocative efficiency as a structural property of the outcomes in their market simulations, they labeled their minimalist agents to have zero-intelligence. Zero intelligence (ZI) studies use minimalist models of agent behavior so as to identify properties of outcomes of social systems that might be relatively robust to a broad range of variations in how agents act. When a property of a social system (e.g., a market, an electorate, or an organization) is identified to be robust under alternative patterns of agent actions, it can be said to emerge from micro-level interactions among behavior of many agents who act within the environment and constraints defined by the social system. It can therefore be associated with the structure of the system instead of being attributed to agent behavior. For example, Gode and Sunder (1993) found that in double auction markets, extraction of maximum possible surplus is relatively robust to variations in agent behavior. Farmer et al. (2005) report that zero-intelligent agent model explained 96% of the variance in bid-ask spreads and 76% of the variance of price diffusion rates across 11 stocks traded in the London Stock Exchange. They conclude that their data "…suggest[s] that institutions strongly shape our behavior, so that some of the properties of markets may depend more on the structure of institutions than on the rationality of individuals (For a broader survey of some of the related literature, see Ladley 2012).

This very emergence of system level properties from statistical mechanics of micro-interactions is the phenomena of structural rationality that we emphasize. We use the insights from this literature to offer a new building block for the study of organizational strategy, and to add a new element to the typology of rationality put forward by Simon in the epigraph.

Our investigation here concerns the methods of modeling used for the formalization of these concepts, not the actual processes involved. As mentioned above, the paths of substantive and procedural rationality models assume different path-making by agents but use similar tools and in general the same method of logical reconstruction to formally capture those paths. Note that these well-established and familiar approaches of substantive and procedural rationality posit strategy-based analysis of organizations. Alternatively, in our attempt to understand organizations, we allow minimally-intelligent agents—that function within the structural constraints of complex systems—the first opportunity to explain macro-level outcomes. Through decomposing modeling of action into three elements and elaborating on the features of modeling methods, we effectively propose a new building block for the science of strategy. Using this third approach allows an understanding of aspects of organizational outcomes through the structures within which agents interact without intelligence, intention, or purpose and thus do not strategize. As such, this approach can enrich theorizing about strategy by including attention to cases where organizational outcomes emerge from complex interactions, but are not derivable or derived from individual actions. For example, a boundedly-rational entrepreneur has been conceptualized as an effectuating agent. In effectuation theory of entrepreneurship (Sarasvathy 2001, 2008), organizational outcomes are not derivable from principles such as bird-in-hand, affordable loss, patchwork quilt, and pilot-in-the-plane, etc.; instead these characteristics of entrepreneurs are generalized from careful direct observation of behavior of many entrepreneurs. Our proposed approach differs from effectuation in that it is not confined within the bounded rationality paradigm. Moreover, it is orthogonal to the existing work in strategy science that builds on characterization of organizations choosing their strategy as a deliberate attempt to compete in market settings (see Michael Porter 1979 as an example).

<Table 1 –About here>

Table 1 juxtaposes our approach to substantial and procedural approaches in terms of the three elements of modeling. Row 1 in Table 1 shows that substantive rationality modeling begins with specification of optimizing agents with personal goals, no cognitive limitations, and logically chosen acts that put them on the path towards their optimal ends. Row 2 shows that procedural rationality modeling begins with specification of a boundedly-rational agent with specified cognitive limitations, aspiration to attain a satisfactory approximation of its goals, plus environment specification in which this agent acts. In contrast to the unique path to the goal under substantive rationality, arriving at satisfactorily close to theoretically derived outcomes subject to bounds on rationality may involve multiple iterations. Note that while substantive rationality implies normative as well as descriptive accounts, the procedural rationality may improve through iterations that can be envisioned as “inner” loops of corrective feedback. While gradual improvement through iterations in (procedural) rationality reflects the reality of limited cognition, it also calls for repeated construction of the path in an adaptive manner, allowing for and generating multiple models of the same phenomenon for agents whose rationality are bounded in different ways leading them on different adaptive paths. Table 2 summarizes this point.

<Table 2 – About here>

Modeling through structural rationality approach involves cognitively and economically minimalist agents, plus environmental constraints within which the agents can act without strategy, even randomly. There is no derivation of actions, strategies or paths, as the aggregate-level outcomes emerge from interaction among many individuals’ actions and environmental constraints.[3]What we propose is to complement the well-established and familiar substantive and procedural approaches to strategy science

[3] The reader familiar with Simon’s scissors might wonder if structural rationality focuses only on one of the two blades in the metaphor: the task environment. The scissors metaphor is not applicable to structural rationality. The two blades of the scissors concern modeling of individual behavior as a result of interaction between agent cognition and the environment in which the agent acts. In contrast, structural rationality models aggregate outcomes which are linked to micro-level interactions only through complexity and emergence.

with structural rationality—a mapping from a combination of minimal non-strategic agents operating inside a set of institutional rules or environmental constraints that define the structure of a system to characteristics of aggregate-level outcomes. This approach allows us to identify and isolate structural features of organizational (aggregate) outcomes from those arising from aspects of individual behavior. The purpose here is NOT to claim that all or even most organizational outcomes are consequences of their structure, and that individual human behavior and characteristics are irrelevant at an aggregate level. Instead, structural rationality refers to the emergence of aggregate outcomes with distinct properties arising from interactions among micro-level actions of many participants. Both organizations as well as individuals may evolve over time depending on their respective environments. (For a discussion of inner versus outer environment see Sunder 2004). Structural rationality applies to the emergence of link between micro and macro levels at all points of time, and to the stages of evolutionary adjustments (Mousavi & Sunder 2022).

Definition, derivation, or description of paths that logically or adaptively link agents to outcomes are not the focus of the emergence-based *structural rationality* approach. Parenthetically, we are aware of the existing use of this very term in philosophy. In particular, philosopher Julian Nida-Rümelin (Gutwald & Zuber 2018) reconciles instrumental rationality with the rational choice theory, whereby the philosophy of action challenges instrumental rationality on normative grounds by questioning the very premise of the latter: Must an action be rational? This question is especially pertinent to modeling practice in economics. Economists have used the logic of instrumental rationality as the basis for axiomatizing rational choice theory, where consistency criterion mandates a unique reasoned path towards achieving a given goal. Nida-Rümelin draws attention to the plurality of reasoning evident in patterns of interaction and meaning. His concept of structural rationality bypasses the problem of accounting for sources of these patterns. In this sense, his view parallels the emergence-based formulation we present here since we also bypass the reconstruction of path(s) from the agent to aggregate outcomes altogether. In recognizing certain commonality with Nida-Rümelin, we maintain the instrumental functionality of rationality without attempting to specify its process in a coherent, logical format. Exercising the latter, however, is the primary thrust of modeling in both substantive as well as in most procedural rationality models. However, in this domain, tradition of ecological rationality is an exception with correspondence and adaptive fit between heuristic strategies and environmental structures at its heart (Gigerenzer, Reb & Luan 2022, Remic & Dekker 2017, Mousavi & Kheirandish 2014, Mousavi et al. 2017, Smith 2008, Gigerenzer et al. 1999, also see the chapter on “From bounded rationality to ecological rationality” in this volume.)

Finally, de-emphasizing the specific characterization of individual choice (of which the ZI approach is an example) contrasts with game theoretic approach to organization strategy, and therefore is a substantial departure from methodological individualism as a “touchstone” of mainstream economics

(Arrow 1994; also, on the centrality of methodological individualism across social sciences, see Longino 2019). We invite the reader to experiment with our non-strategic stance and get a taste of structural rationality to explore complexity and emergence of outcomes in organizations. The rest of this chapter is a companion for such exploration. Section 2 clarifies our intended meaning of complexity and casts it as a system-level property. Section 3 brings home our main points on institutions and rationality.

2 Complexity

Complexity arises in models in several ways. *Constructive complexity* involves the familiar dictionary meaning of a complicated or intricate nature of an object, phenomenon, or process. *Representational/computational complexity* refers to the difficulty of solving a problem, or the time it takes for a given algorithm to find the solution. These constructive and representational/computational aspects are not the forms of complexity we explore here. We reserve the term complexity for a third meaning familiar from complexity theory, commonly labeled as *structural complexity*. It refers to the emergent properties of outcomes observed at more aggregate level that arise from difficult-to-analyze local interactions among elements of the system at a level next beneath.

To deal with different aspects of complexity, each approach to rationality devises a different modeling method. Substantive rationality modelers devise abstraction and axiomatization to retain optimizability throughout the construction of the path. Procedural (bounded rationality) modelers, in the main, study the adaptive use of heuristics and their ecological rationality (see the comparison of the axiomatic-based approach to ecological rationality in Gigerenzer 2019), introduce approximations and generate sub-optimal or near-optimal outcomes. These methods have been extensively applied to organization strategy. Our proposed structural rationality approach is fundamentally different from these methods in bypassing the path-building stage of modeling altogether; it offers a framework for exploring emergent outcomes that arise from complex interactions. Our approach also differs from the line of work built on using complex adaptive systems to study organizational structures and outcomes (for an extensive review of management strategy in relation to complex adaptive systems, see Anderson 1999, and for internal vs. external complexity see Jost 2004.

2.1 Organization as a complex physical phenomenon

In conventional approach to organizational behavior, both the structure as well as the properties of organizations are sought to be derived from the nature, preferences, abilities, circumstances, and motivations of their constituent parts—the individual members. In our proposed approach, the complexity of a system arises from the presence of non-linear feedback loops that may generate, from even small differences in initial conditions, large and unpredictable consequences for the system outcomes. Such properties, well documented in physical and increasingly in social systems, make it impossible to have any simple mappings (e.g., regression and analysis of variance models often used in many social sciences) between the properties and behavior of individual components of a system, and the system-level outcomes.

Non-linear feedback loops are generically present in organizations just as they are in physical systems. Since exploration of complexity has already advanced in physics, using that scaffolding is prudent for our study of its consequences in the study of organization strategy. Turner and Killian's (1987) emergent social norms theory and other theories of crowd behavior (see Reicher 2000), and theories of fashions and fads (Bikhchandani et al. 1992) are examples of social science attempts to capture non-linear feedback in complex systems and its consequences.

Use of physical laws to frame the structure for modeling human behavior has solid precedents. In a context different from ours, movement of large crowds has been modeled as the flow of fluids (see Helbing 1992, Helbing 2001, Moussaid & Nelson 2012). However, that does not mean the individuals in a crowd lose their identity or agency; it only means that in analyzing the behavior of a large crowd of human beings as a whole, analysis of an individual's conscious thoughts, effort, actions and strategy—the higher faculties with which we humans so proudly believe ourselves to be uniquely endowed—may be of only limited value.

The approach we discuss in the current chapter is an application and extension of a broader program outlined in Mousavi and Sunder (2019). They present a three-tier framework for the study of action, and propose modeling in this order: physics, biology, and socio-psychology. Following this order, a modeler starts by choosing a universal law of physics such as the principle of least action (PLA) to organize the observed phenomenon. Choosing PLA then specifies the method of decomposing an observed phenomenon of interest in terms of three components: external or fixed elements, optimization or action element, and configuration of the resulting path between the start and the end points. Applying this method to model a player catching a fly ball consists of the following. Start and end points are external elements, as is the time of catch when runner and the ball arrive at the same point, the path of the ball (in vacuum) is a parabola. Notice that both external elements and the path are merely physical entities. Before discussing and configuring the physical form of the action element, we digress to address a commonly asked question in this context: *How* does the runner catch the ball? Richard Dawkins famously answered the question from an evolutionary biology stance:

> When a man throws a ball high in the air and catches it again, he behaves as if he had solved a set of differential equations in predicting the trajectory of the ball. He may neither know or care what a differential equation is, but it does not affect his skill with the ball. (1976, p. 96)

Cognitive scientists have formulated an explicit answer based on the evolutionary capacity of holding gaze on moving objects that humans and animals are endowed with. The process has been dubbed the Gaze Heuristic (Hamlin 2017), referring to keeping the angle of gaze on the ball constant with respect to the horizon while moving towards the ball until the person and the ball meet just-in-time before the ball falls to the ground. It is in addressing the practice of modeling *how* of action, that Mousavi and Sunder (2019) choose to start with physics instead of the higher faculties, such as cognitive and evolutionary endowments. By reversing the traditional order of modeling and starting with physics, they formalize the observed phenomenon. In their three-tier framework, an action is simply viewed as a movement between two points to be specified. The thrust of the exercise is to remain bounded within physics until its explanatory power is fully exploited. In modeling of catching the fly ball, the action element that fits the physics law of PLA is simply the *change* in the gaze angle that has to remain near zero; no biological or higher order endowments are called upon. Table 3 depicts a comparison between the elements of modeling in the three-tier framework: the extant exercise versus the proposed reversed order. Following the latter method, the modeler looks to biology (second tier) and uniquely human endowments of social psychology (third tier) for assessment of residual observational variation only after the explanatory power of physics has been fully used.

<Table 3 –About here>

Extending this approach, we propose viewing an organization, at a first tier of inquiry, as consisting of interacting individuals treated as if they are particles with given properties. An organization is thus defined by the rules of interaction among these individuals who, stripped of motivation, do not devise strategies. Since it bypasses strategy, our approach may be seen as an alternative to game theory that explores systems populated with strategizing agents. Although strategies as well as organizations may evolve over time, we focus on the linkage between micro behavior and macro outcomes at *any* given point in time. One may ask if the everchanging landscapes should call for the organizations to anticipate the future and strategize more, not less. We favor starting with simple and robust structural explorations to learn about their limits before resorting to more complex and anticipatory strategy construction. Corroboration of this approach in reality is evident in simple rules for dealing with a complex world of entrepreneurship studied by Eisenhardt and colleagues (see, e.g., Sull & Eisenhardt 2016). We intend to focus on elaborating on organizational outcomes, the “givens” in Simon’s terminology, which can be configured without reference to strategies—an extension of allocatively efficient outcomes arising from complex interactions among zero-intelligence agents in markets. All arguments we put forward on organizational structure are susceptible to being amended by dynamic approaches to organizational processes for dealing with external changes of variant nature and frequency.

The first tier of our approach is purely physical. It abstracts away from the "human" elements, treating organization as a collection of interacting particles subject to a set of rules given by organization's structure. Since the properties of the whole may emerge from micro-level interactions among components, decomposing the collective to its elements is neither feasible nor attempted. To put this view in perspective, consider the fact that known matter in the physical universe has cohered into discrete mutually interacting aggregates at various levels—asteroids, satellites, planets, stars, galaxies, and clusters of galaxies. At the first level of approximation, astrophysicists examine the properties of these heavenly bodies without much attention to the detailed properties of the particles that cohered to form them. The laws of physics brought these particles to cohere in discrete bodies without collapsing the universe into a single mass (indeed, there is evidence that the universe is expanding and bodies in it are flying apart from one another). To explain this agglomeration into clusters of varied shapes and sizes, the law of gravity applied to particles in a gravitational field seems to suffice.

Aside from astronomy, a well-defined organization of smaller elements into collectives with predictable attributes occurs at innumerable other levels in physical (inanimate) nature—rivers, tornadoes, hurricanes, clouds, rocks and crystals, mineral deposits, volcanoes, fires, and waves. As with human organizations, it is difficult to predict the existence of such "organizations" in nature at any particular time or place; yet, information about some of their aspects can help school us about other unobserved aspects of phenomena. This predictability implies that even if they might have arisen through random processes governed by laws of physical nature, the outcomes can be well "organized" and have emergent properties often absent, or undetectable, in their constituent elements.

By analogy, we can think of human organizations as agglomerations of people brought together by the "gravitational" forces of human sociality, economies of scale, and network effects. The same argument would apply to collectives or "organizations" that we observe in many biological organisms—a pride of lions, a gaggle of geese, or a cloud of starlings, a beehive, or a termite hill. Even the ganglia in a nematode worm provide a simple version of a biological organization (Cherniak 1994).

The three parts —agents, paths, and outcomes—presented in Table 1 (Section 1) appear in many models of different forms of organizations. For example, Boyd & Richerson (2005) compile and share their decades of research on how genes and cultures co-evolve to shape sociality of our species, and Jackson (2008) uses network analysis to portray human behavior (including strategizing) arising in a host of individual and social contexts, by drawing on psychology, economics, sociology, computer science, and physics. Our proposal adds to, and offers an alternative approach for studying outcomes, while bypassing the construction of paths, and limiting the agent to minimal levels of rationality. In what follows we explain how agents with minimal or no strategy and intelligence can generate efficient aggregate outcomes depending on structure of their environment. Hence, structural rationality.

2.2 Near-decomposibility versus structural continuity

Each organization has its structure that defines the environments within which various tasks are pursued. We ask whether the complexity of tasks must be reflected in the complexity of strategies to achieve them[4] (this use of complexity, only referring to complicated format of tasks, is different from what we specified as our intended meaning of the term earlier). We note that when phenomena of interest occur at a higher level of aggregation, it is not necessarily useful to dig deep into the behavior of micro-level components of the system, akin to the way in which Simon pictured the scientific endeavor:

> This skyhook-skyscraper *construction of science* from the roof down to the yet unconstructed foundations was possible because *the behavior of the system at each level depended on only a very approximate, simplified, abstracted characterization of the system at the level next beneath.* This is lucky, else the safety of bridges and airplanes might depend on the correctness of the 'Eightfold Way' of looking at elementary particles." (1996, p. 16; emphasis added)

Practical examples of this wisdom about decomposability of systems at various hierarchical levels are present in all fields of human endeavor. According to Simon (2000, p. 8): "[Such systems] are arranged in levels, the elements at each lower level being subdivisions of the elements at the level above. Molecules are composed of atoms, atoms of electrons and nuclei, electrons and nuclei of elementary particles. Multi-celled organisms are composed of organs, organs of tissues, tissues of cells." Simon argues that near-decomposability is an efficiency-enhancing feature in evolution because it enables evolution of one layer through natural selection without too much drag from interaction with other layers. Although Simon also mentions evolutionary advantage of near-decomposability across layers (see his example of specialization of labor across sub-units), there are arguments in biology to the contrary, such as Darwin's (1858), and Gould's (1985) argument about functional change and structural continuity in evolution of various organs that makes evolution possible.

Visual images can be broken down into their elements all the way to the smallest pixels discernible to the human eye. Yet, landscape painters do not paint each leaf of a tree nor each tree in a forest, just as portrait painters do not paint each hair on a head or crease in the skin. Instead, painters skillfully apply paint with practiced strokes of a brush or knife—which may appear to be chaotic on

[4] This question has been famously addressed with a resounding "No" in Simon's (1956) ant moving along a sandy beach in complicated paths following a simple rule: change direction, when hitting an obstacle. Here, we consider this problem from a different angle of aggregate level emergence.

closer scrutiny—to produce beautiful art as seen from a few feet away (see Monet's (1877) *The Turkeys* in Figure 1). In another case of visual aggregation, the 1968 Apollo space mission photograph of earth as a blue marble suspended in black space above lunar surface exhibits hardly any similarity to a close up photograph of grass in a lawn on the same surface (Figure 2) changed humanity's perspective on the earth, accelerating the environmental awareness and movement. At the aggregate level, in the view from deep space, the details of each blade of grass one sees sitting in a lawn gets discarded and a totally different previously unseen big picture of our place in the larger universe—all eight billion of us clinging to a ball floating in empty darkness—emerges before our eyes. Neither of the two views of the earth is better or worse, nor is either derivable from the other. In Buddhist *Madhyamika* philosophy, there is a parallel to this concept with *co-dependent arising* (*pratityasamutpada* in Sanskrit, see Macy 1979).

<Figure 1 –About here>
<Figure 2 –About here>

These examples illustrate that the distance from the object matters not only to how much is seen but also to what is seen by the observer. Distance being a physical magnitude, its effect on transmission of information is subject to laws of physics. But the difference it makes to perception is a matter of cognition and neuroscience. Studies of optical illusion focus on the gaps between these two perspectives.

Decomposability of systems into their components does not mean that the properties of systems are necessarily derivable from the properties of their components. The time-keeping property of a watch cannot be derived from identifiable properties of its components any more than the life of an organism can be attributed to the properties of its organs, or the frenzy of a mob traced back to the personalities, motivations, and circumstances of individuals in the group.

The new insight we attempt to provide here comes from examining the properties of various organizational structures when they are assumed to be populated by zero- or minimal-intelligence agents. In economics, Gode and Sunder (1993) showed that the aggregate level allocative efficiency of simple double auctions[5] is robust to variations in agent behavior.

> Some features of market outcomes are largely robust to variations in the decision-making behavior of agents who participate in them. Allocative efficiency, a key measure of market outcomes, is one such feature. *Adam Smith's conclusion that the allocative efficiency arises from individual pursuit of self-interest may be more general than it appears.* Efficiency is achievable

[5] In a double auction both buyers and sellers, endowed with their respective private values of costs, are free to announce bids (prices at which they are willing to buy) and asks (prices at which they are willing to sell). Whenever the bid price equals or exceeds the ask price, a transaction is executed at a price between the two.

> in double auction markets even if agents act randomly within their budget constraints. Random choice within one's opportunity set is, at best, only a weak form of "pursuit of self-interest." The use of the maximization assumption to derive market equilibria in economics and the findings from cognitive psychology that individuals cannot and often do not know how to maximize need not be seen to be mutually inconsistent. Market institutions may be the society's way of dealing with the human cognitive limitations. In classical environments, markets can approach the aggregate maximum even if the individuals do not know how to. (Sunder 2004, p. 518-519)

Specifically, markets populated with simple ZI agents can have the same allocative efficiency as similar markets populated by profit-motivated human agents. In other words, the surplus extraction property of these markets is relatively robust to variations in agent behavior. This approach has been applied to study a variety of systems of which a few examples are given below.

Much research has followed the initial report on findings on ZI agents, including attempts to bridge the gap between zero and fully rational agents. Adding elements of rationality to agents does, as one would expect, tend to bring more aspects of aggregate-level outcomes—especially transaction prices—closer to observations from institutions populated with motivated human agents. Readers interested in the literature on incrementing the intelligence of agents by equipping them with more sophisticated strategies, such as ZI-Plus (ZIP) can find a rich sample of published work, e.g., Chan, LeBaron, Lo and Poggio (1998), Gjerstad and Dickhaut (1998), Yeh (2007, 2008), Cliff (2009), Chen, Zeng and Yu (2009), Huber, Shubik, and Sunder (2010), De Luca and Cliff (2011), and Palit, Phelps, and Ng (2012). This literature on outcomes of markets populated with agents of varying levels of intelligence and trading strategies, and comparisons with human agent markets, is of substantial interest, especially in theories of learning and computational economics and psychology. The question sought to be addressed in this literature is: What features of artificial agents are sufficient to achieve market-level outcomes close to markets populated by human subjects in the laboratory or field?

However, the direction of this pursuit to create artificial intelligence is diametrically opposite to the focus of our present inquiry aimed at exploring emergence and structural rationality as an alternative to the conventional modeling practice of constructing and deriving strategies, paths and outcomes from behavior of goal-oriented rational agents. The key feature of the present inquiry is not the characteristics, especially intelligence, of agents, but about the structural properties of social institutions that are relatively robust to agent behavior. This is an alternative to game theoretic strategy refinement, and reinforcement and other schemata based on learning. For example, markets with minimally intelligent agents can generate outcomes that closely approximate the equilibrium results from Walrasian *tâtonnement* (Crockett, Spear, & Sunder 2008) even under a variety of market protocols (e.g., sealed-bid and double auctions). Critical assessments and explorations of the limitations of the initial and subsequent findings of ZI agents are available in a body of literature, including but not limited to the following: Cliff and Bruten (1997), Chen and Tai (2003), Posada, Hernández and López-Paredes (2006), Miller (2008), Schwartzman and Wellman (2009), Othman and Sandholm (2010).

2.3 From markets to organizations

Economic studies of markets have revealed institutional properties governed by structural rationality. This phenomenon is summarized in Sunder (2004):

> As social artifacts, markets are the arena for the interplay of demand and supply. Functionality of markets can be assessed by their robustness to certain environmental variations and responsiveness to others. We prefer markets to be robust to variations in individual cognitive capabilities and responsive to their wants and resources. If creation without a creator and designs without a designer are possible, we need not be surprised that markets can exhibit elements of rationality absent in economic agents.

Translating structural rationality of complexity from the economics of markets to organization science calls for specifying answers to at least three important questions.

- What are the defining features/characteristics of organizations and institutions?
- What are the important aspects of the environment in which the organization operates?
- What are the important characteristics of outcomes of organizations?

Organizations are viewed as networks of economic agents, each endowed with knowledge, opportunity sets and preferences, related to one another by links of communication, expectations, and opportunities for voluntary exchange. In this sense, each family, neighborhood, school, hospital, town, professional association, and country is an organization. A society has many organizations with overlapping participation since any single individual typically participates in numerous organizations in a variety of roles, as Barnard (1938, p. 73) eloquently put:

> I select at random a man who is chiefly identified by his connection with the organization with which I am also ordinarily identified. He is an engineer whose career and living for many years have depended upon that organization. Without enquiry, I know he has the following organization connections also: He is (1) a citizen of the United States, the State of New Jersey, the County of Essex, and the City of Newark—four organizations to which he has many inescapable obligations; he is a member of (2) the Catholic Church; (3) the Knights of Columbus; (4) the American Legion; (5) the Outanaway Golf Club; (6) the Democratic Party; (7) the Princeton Club of Newark; (8) he is a stockholder in three corporations; (9) he is head of his own family (wife and three children); (10) he is a member of his father's family; (1l) he is a member of his wife's family; (12) to judge from his behavior he belongs to other less formal organizations (but often seems not be aware of it) which affect what he wears, how he talks, what he eats, what he likes to do, how he thinks about many things; and (13) finally he gives evidence of "belonging" also to himself alone occasionally. Lest it be thought that his "major" connection is predominant, and the others trivial, it may be stated that he devotes to it nominally less than 25 percent of his approximately 8760 hours per annum; and that actually while he thinks he is working, and despite

> his intentions, he dreams of fishing, reflects on family matters, and replays a part of the previous evening's bridge, etc.

An institution is a social framework of norms, expectations, laws, rules, customs, and contracts that defines the context or environment within which organizations are created, run, and liquidated (For an extensive discussion of institutions in relation to economics, see North 1990). For example, marriage and family are two institutions within which millions of specific couples and kinship groups live. Nation state is an institution that defines the context of much larger groups of individuals, often but not always with shared culture, language, laws, customs, and governance who live in a shared territory within which they are free to move. A democracy can also be seen as an institution, which many nation states and other forms of organizations may choose as their framework. In common usage, the term institution is sometimes used for a specific organization to emphasize its importance, longevity, name recognition and good reputation. Yet, as a technical term, it seems better to reserve it for a more abstract concept of some shared characteristics of a given *class* of organizations. In this sense, marriage and family are two institutions, whereas a married couple exists in the institution of marriage, and together with their children and some others, may exist in the institution of family, clan or tribe.

The meaning of *goals* of an organization remains ambiguous. When an organization is seen as a set of mutual expectations and contracts among various agents, the union of goals of all participating individuals can also be attributed to the organization. However, this set is almost always quite diverse, and not a good instrument for attributing agency to the organization itself. Often, the goals of some subset of organization's participants, e.g., owners of capital or top managers, is also attributed to the organization itself. This practice has little theoretical basis and is not useful for analysis. The concept of organizational strategy likely arises from this perspective on organizational goals, and we shall not defend it. Instead, we choose to focus on assessing how organizational outcomes emerge from complex interactions among the actions of their participating agents within the constraints of its structure, using ZI approach to agent behavior. The existing findings that in certain markets agents do not have to devise intelligent strategies to produce efficient outcomes (ZI results) justifies this approach to the study of strategy in organizations. Stripping agents of strategy relieves modelers from the challenges of capturing and representing complicated individual objectives and capabilities. What remains can be viewed as the environment consisting of laws, social norms, and expectations in which the agent is constrained to operate (See Gode and Sunder 2004 and Sunder 2006 on economic interactions within constraints).

Performance of organizations is measured by characteristics of their outcomes including efficiency, effectiveness, longevity, etc. Characterizing outcomes can be a first step towards sorting out what features of an organization are relevant to the specified outcome characteristics. We are currently examining with simulations the relevance, or lack thereof, of distinction between hierarchical and centralization in an organizations for their efficiency. We have not found solid evidence to this effect yet but are devising different schemes to probe the idea through defining measurable proxies as explained below.

The effectiveness of an organization is assessed by its ability to reach its purported objectives or goals, without regard to the necessary resource sacrifices. If a business sets a goal of reaching sales revenue of $1 million, and sells $900,000, it is 90% effective.

Efficiency modifies effectiveness by assessing the achievement of goals considering the resources sacrificed in the process. When goals as well as sacrifices can be quantified and reduced to a single unit of measurement in denominator and in numerator, respectively, (a special and unusual case) efficiency takes the form of the output/input ratio. Engineers may assess fuel efficiency of a car as a ratio of miles/gallon, and economists may assess the efficiency of a factory as the ratio of the sum of values of all its products and the sum of costs of various inputs such a labor, material, and machinery. Under the network of (or set of contracts among) agents, representation of organizations alluded to earlier in this section, we can employ the following simple definition of efficiency. Calculate the sum of resources all agents receive from the organization, and the sum of resources sacrificed by all agents in their relationship with the organization after reducing them, if possible, to a common unit of measurement. Then, in resource units, organizational efficiency can be defined as the difference between these two sums because that is the total surplus generated by the organization for society. Alternatively, in percentage terms more often used in engineering, efficiency can be defined as the ratio of these two sums. We assume that the challenging problem of commensurability—reducing all resource flows to a single unit—has somehow been addressed because all resource flows are rarely in the same units and may not always be quantifiable.

3 Structural Complexity of Organizations

To address the structural complexity of organizations, we focus on organizational outcomes—“givens” in Simon’s terminology. Simon named two primary forms of rationality used in the social sciences for modeling human behavior: (i) substantive rationality (mainly used in economics) to optimally characterizes agent behavior and outcomes, and (ii) procedural rationality (used across the social sciences) to explore the processes that generate individual behavior. We argued that modelers in both approaches share a common ground in the construction of best possible paths based on individual choice derivable from specifications of the agent rationality. Bringing the third notion of structural rationality into the mix, we set out on a new exploration into “organizational behavior” that leapfrogs path (re)construction and strategizing altogether. Viewing outcomes as (given) emergent phenomenon, the task of modeler becomes specifying the structure of environments, which generate outcomes through complex interactions among agent actions. This third approach to rationality focuses on identifying those characteristics of aggregate-level outcomes which are relatively robust to variations in agent behaviors and strategies. To elaborate, we recounted the three decades long line of work on randomly acting agents in double auction and other markets, namely, the zero-intelligence agent.[6]

We argued that development of a strategy science would benefit from incorporating the cases of organizational outcomes that are not derived from agents' deliberate strategy choice, but that simply emerge from the structure of the organization as defined by its operating rules. Examination of the efficiency of outcomes of organizational structures under a variety of agent behaviors, especially the extreme of random behavior, is a useful approach to identifying organizational performance characteristics that arise from their structure rather than the specifics of the behavior of their participants. This approach dispenses with methodological individualism that governs both substantive and procedural rationality modeling.

The central thesis of the current chapter is twofold. First, the study of strategy as a science can start from clarifying the case of organizational outcomes in absence of deliberate strategies. Second, the zero-intelligence agents can serve as a starting point in investigating structural properties of organizations. With these two premises, we proposed exploration of the complexity in organizations from the lens of structural rationality.

Procedural rationality and (structural) emergence approaches have two important common features. First, these two share the common ground of admitting a multiplicity of paths to a given outcome. The relationship between structural rationality of emergence and ecological rationality is described by Sunder (2009, p. 107) as follows. "Deliberate as well as intuitive actions that arise beyond the reach of conscious reason are taken within the social environment defined by the rules and institutions and interact in complex ways. These interactions define institutions and give rise to the aggregate level outcomes and institutions. The resulting tacit knowledge and tendencies constitute the ecological order of rationality beyond our self-awareness."

Second and perhaps more important common feature of procedural and emergence-based structural approaches to rationality is their greater breadth in the scope of the applicability (and likely

[6] While the statistical characterization of zero-intelligence agents acting randomly according to a uniform distribution in the context of computational experiments is relatively recent, the general idea has earlier roots. According to Jaffe (1976, 521), in Carl Menger, a pillar of Austrian economics, thought "Man … far from being a 'lightening calculator,' is a bumbling, erring, ill-informed creature, plagued with uncertainty, forever hovering between alluring hopes and haunting fears, and congenitally incapable of making finely calibrated decision in pursuit of satisfactions." This description contrasts sharply with Veblen's (1919, p. 73) widely known criticism of "man" in Austrian economics as a "…lightning calculator of pleasures and pains, who oscillates like a homogeneous globule of desire of happiness under the impulse of stimuli that shift about the area, but leave him intact.)

effectiveness) as compared to substantive rationality.[7] Substantive rationality is concerned with optimum solutions which are definable only when the decision problem is fully specified, i.e., when all possible options, states of the world (and their probabilities when appropriate) are known. This is hardly ever true outside the completely structured environments, such as a game of roulette in a casino. Savage (1954) labelled such situations as the "small world" scenarios, where knowledge of states and their probabilities renders it possible to conduct "risk" analysis, and optimum is well-defined to deploy the concept of substantive rationality. But in Savage's "large worlds" in which we actually live and work, either the states of the world, or their probabilities, or both are unknown. Knight (1921) clearly distinguished this environment of "uncertainty" from the abovementioned "risk". Substantive rationality with its total dependence on knowledge of optimum solutions cannot be deployed under uncertainty. In contrast, procedural rationality with its emphasis on bounded cognition, rules of thumb and heuristics and structural rationality face no such limitations, and perform robustly in worlds both small and large, under risk as well as uncertainty.

Aggregate outcomes can be descriptively relevant without individual optimization. This issue has been a challenge in economics (Simon 1978, 1996), and has been addressed from many perspectives. In laboratory experiments, observed behavior of subjects "often violates] the canon of rational choice when tested as isolated individuals," whereas, "in the social context of exchange institutions serve up decisions that are consistent (*as though by magic*) with predictive models based on individual rationality" (Smith 2008). In economics, the competitive model "despite of its mathematical complexity, is very crude when placed in the context of ... interactive markets and behaviors. Nevertheless, if the assumptions of the model are applied with an 'as if' interpretation the resulting model is very powerful. ... The mathematical problem was solved quickly and without all the relevant information existing in a single place ... Some sort of parallel processing appears to be taking place, but its form *remains a mystery*" (Goodfellow and Plott, 1990, p. 7). This magic embedded in the processes governing complex interactions has been extensively studied as strategy choice attributed to the operators inside an organization. In our proposed approach, however, it is left to remain a *mystery* and thus allowing for the success of unsupervised processes in organizations.

In this chapter, we looked at three approaches to rationality for modeling human behavior and organizations. Conventionally, both the structure as well as the properties of organizations are sought to be derived from the nature, preferences, abilities, circumstances, and motivations of substantive or procedurally rational agents. We introduced a third approach of structural rationality that bypasses the reconstruction of paths. While an optimizing agent follows a logical path to arrive at the optimum

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7. Authors are grateful to Gerd Gigerenzer for raising this important issue.

outcome, a boundedly-rational agent can arrive at a satisficing outcome by choosing from a variety of ecologically rational paths. A zero-intelligence agent, on the other hand, devises no strategies. Our paper initiates an effort to develop a configuration of organization with ZI agents as a new building block for the science of strategy. Here, specification of the path or strategy is not of primary concern. Instead, we extend on a three-tier framework within which human action is explained, at its first approximation, by physical principles. We propose to transition from individual to collective through a similar physical-based configuration of the emerging properties of organizations. This idea can be viewed as a contribution to the literature on the structural aspect of complexity, wherein properties of a collective need not be derived from properties of its elements.

Our position in on theoretical concepts of complexity is twofold. First, we distinguish between its common sense and formal mathematical meanings. Constructivist efforts, including those of strategy science, are mainly concerned with the common-sense meaning of complexity (i.e., complicatedness) and simplification of it by making explicit representations of the processes that lead to outcomes. This practice can be precise—as in substantive rationality—or made operationally tractable by allowing for sub-optimality—as in procedural/bounded rationality. Second, we use the mathematical definition of complexity (as conceived in complexity theory) and put it at the center of our inquiry. The focus is on the structural or aggregate phenomena whose properties are not to be sought directly and exclusively in the properties of its elements. We start with observed outcomes as given, and thus minimize the need for specifying goals and strategies.

If a strategy is viewed as consciously building a path towards an intended end, we propose studying organizations sans strategies. For this reason, ours may appear to be an unusual contribution to strategy science (and more like anti-game theory). But developing the science of strategy also calls for exploring the properties of organizations that are achievable without a strategy. Putting aside all outcomes that emerge from minimal-intelligence or non-strategizing agents within the structure of an organization leaves us with the outcomes associated with deliberate and possibly complex strategic behavior. This subset of outcomes observed or desired (that do not simply result from organizational structure) can be thus understood by reconstructing the strategies that would generate them. We hope that such a radically different perspective will stimulate heterodox scholarly thinking and prompt further debate, adding to the original frames of organizational behavior put forward by Herbert Simon.

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Tables and Figures

Table 1: Characteristics of agent, path and outcome vis-á-vis three forms of rationality

Three Parts of Model / *Approaches to Rationality*	**Agent**	**Path**	**Outcome**
1. Substantive	Goal optimizer	Optimized: logically constructed	Optimum
2. Procedural	Goal satisficer, adaptive, heurist, imitator, maximiner	Formal: Logically constructed to reflect agent characterization (Actual=boundedly constructed)	Boundedly/Ecologically rational (near-optimum if optimum is knowable)
3. Structural	Minimally-intelligent	Complex interaction defined by structure and its constraints	Emergent and possibly efficient

Table 2: Ecological rationality as refinement of modeling in three approaches to rationality

Ecological Rationality for modeler can be seen as correcting for difference between empirical observation and model outcomes. Substantive rationality modeling does not involve path refinement but characterizes an optimal path, structural rationality does not attempt path characterization; both focus on given outcomes.

Feedback loop	**Outer loop**	**Inner loop**
Substantive rationality	Present	Absent
Procedural rationality	Present	Present
Structural rationality	Present	Absent

Table 3: To catch a ball can be modeled in physical terms, with and without drawing on higher faculties.

The Methods of Modeling	***WHAT:*** **Fixed/ exogenous element**	***HOW:*** **Action element**	**Observed Path**
Conventional approach, using animate faculties	Time a fly ball takes to reach ~1.5 m above ground	Use the evolutionary capacity of holding gaze on a moving object	A curved path, depending on when the angle of gaze is first fixed
Bounded to the first physical tier of the three-tier framework	Same as above	Keep a *fixed angle* of gaze (change=0)	Same as above

Figure 1: Claude Monet (1877): The Turkeys (from Artstor.org) with Area of Detail

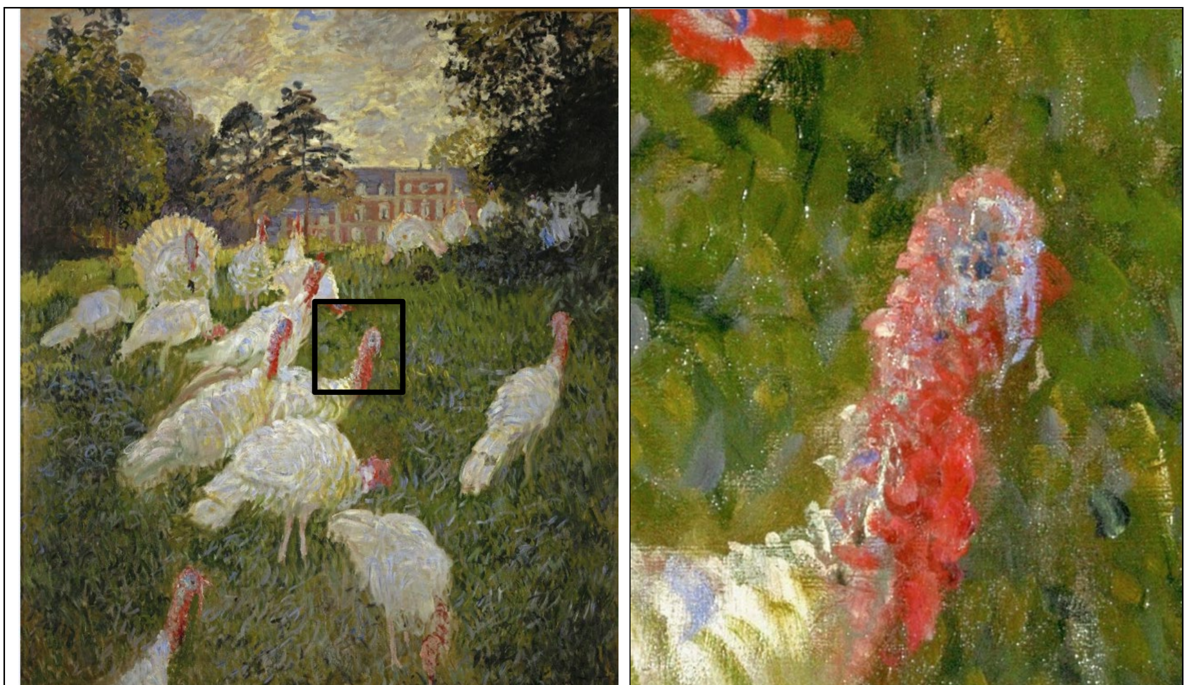

Figure 2: Earthrise above Lunar Surface, from Apollo 8, Christmas Day, 1968. NASA and Lawn Grass
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