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Artículo

Complexity and the Austrians

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Abstract

This article examines the similarities between the Austrian research program and the complexity approach in economics. We argue that the Austrians, especially Hayek, anticipated many topics addressed by the complexity approach. Besides investigating the extent to which complexity themes arise in the Austrian theories, we discuss the methodological reasons for the affinity between the two theoretical traditions. After arguing that computational models could assist in resolving a dispute in the modern Austrian market process theory, we conclude the article with a Hayekian critique of certain aspects of the lock-in models developed by the complexity tradition.

Key-words: complexity, self-organization, Austrian school.

Resumen

Este artículo examina las similitudes entre el programa de investigación austríaco y el enfoque moderno de la complejidad en economía. Argumentamos que los austríacos, especialmente Hayek, anticiparon muchos temas abordados por el enfoque de la complejidad. Además de investigar el grado en que estas cuestiones surgen en las teorías austríacas, se discuten las razones metodológicas para la afinidad entre los dos enfoques. Después de argumentar que los modelos computacionales pueden ayudar a resolver una controversia en la moderna teoría del proceso de mercado de los austriacos, se concluye con una crítica de Hayek de ciertos aspectos de los modelos de lock-in desarrollados por el enfoque de la complejidad.

Palabras claves: complejidad, auto-organización, escuela austríaca.

Introduction.

Though relatively unknown among economists, the science of complexity has been established as a research program able to provide explanations for phenomena that, although typically studied by disciplines in different fields of knowledge, share common elements, which justifies a unified treatment. Several examples of such phenomena, called self-organizing complex systems, are economic in nature, and therefore the study of this approach deserves closer inspection by economists.

Self-organizing structures present some typical properties: they evolve continually, often as adaptation to a changing environment, and sometimes they show apparent functionality, i.e., these structures appear to follow some purpose. Such structures are composed of elements whose principle of motion is not directly related to the global properties of the system, so that the whole has characteristics different from those presented by its parts. These elements behave according to relatively simple rules. Additionally, the interaction between the elements is local: each one relates to a relatively small number of elements in its neighborhood.

The ways in which bees stabilize the temperature of the hive (Miller and Page 2007, p.15); ants tend to maximize the distances between the colony, the garbage dump and cemetery (Johnson 2002 p.24); and how the actions of humans are coordinated in markets—as well as the evolution of money, social norms, and language—are all examples that fit this description.

The problem facing students of these phenomena is to construct a theory that explains how a complex order spontaneously emerges from the interaction of simple elements. Any theory proposed to address the problem cannot assume an external element that controls the system from outside: the explanation must be bottom-up, from simple elements to the complex structure itself.

The term "complexity" may seem inappropriate, contradicting the notion that all theory is a simplification. But we still use it because it refers to the idea that the central elements of complex phenomena are overlooked if we only apply analytical tools that use static models with overly aggregated variables, because the emergent properties of complex phenomena are explained in terms of structural relationships among their elements.

This leads to an old methodological dilemma: drastic simplifications are criticized for their lack of realism, but to take into account the richness of different aspects of a phenomenon, as the historicist desires, leads to a mass of data that defies understanding. The solution found by the complexity approach (CA) to science is the use of computational models. These can represent systems composed of multiple heterogeneous agents that use simple rules and interact locally, resulting in the emergence of spontaneous orders. Although in these models the number of particular outcomes is virtually infinite, repetition of the simulations enables us to discern patterns or regularities in the behavior of those systems.

The study of complex systems has developed gradually over the twentieth century. Several theories dealing with complex phenomena were developed, such as general systems theory (Bertalanffy 1969), cybernetics (Wiener 1948), and chaos theory. Due to its multidisciplinary nature, the study of complexity has collected contributions from various fields, such as mathematics, chemistry, evolutionary biology, and computer science, generating a diverse repertoire of techniques. In particular, the development of computers allowed many programming techniques to be widely used in models, such as genetic algorithms (Holland 1992; Mitchell 1998), employed, among other purposes, to represent learning processes of agents and cellular automata (Wolfram 1984), used to depict systems displaying local interactions.

Over time, it became clear that the different systems studied had common elements, which gave impetus to the search for a unified discipline.[1] An important step in this task was taken by researchers at Santa Fe Institute in the United States, an interdisciplinary center focused on the study of complex adaptive systems.

The CA in economics, driven by this effort, models markets as adaptive systems in which over time (not statically), coordination patterns (not necessarily equilibria) emerge (it is not assumed) that show continuous adaptation to change (not optimality). These patterns are obtained by decentralized interaction (not coordinated by a Walrasian auctioneer) between heterogeneous agents (not by representative agents), with partial (not perfect) knowledge, the result of a learning process from which unanticipated results or novelty frequently arises. Additionally, agents act according to a set of rules (rather than maximization of known functions) (Arthur et.al. 1997). The agent-based computational models inspired by this tradition seek to represent many characteristics listed above.[2]

If economies are indeed complex adaptive systems as described by the CA, it would be natural to search through the history of economic thought for

1 There are many good introductory books to the science of complexity: Flake (1998), Miller and Page (2007), and Mitchell (2009).

2 For an introduction to computational models in economics, see Tesfatsion and Judd (2006).

anticipations of this approach: the Smithian invisible hand metaphor is one easily identifiable example. However, the most striking example is found in the work of the Austrian economist F.A. Hayek. Reading the complexity literature provokes the feeling that we are indeed revisiting Austrian themes. This is attested by Brian Arthur, a researcher at the Santa Fe Institute:

> Right after we published our first findings, we started getting letters from all over the country saying, 'You know, all you guys have done is rediscover Austrian economics' … I admit I wasn't familiar with Hayek and von Mises at the time. But now that I've read them, I can see that this is essentially true." (Tucker 1996)

As it often happens in any history of ideas, in seeking precursors we run the risk of "Whig history". This article, whose object of study is the relationship between the Austrian school (AS) and the complexity approach to economics, seeks to show that this danger is small in relation to the Austrian writers, insofar as the central themes of the CA are effectively present in several Austrian theories.

To show the affinity between the two approaches, we initially examine Menger's theory of the evolution of money and Böhm-Bawerk's development of Austrian capital theory. After that, we show that complexity is a central feature of the problem that defines Hayek's research program. In order to establish this, we must first examine his article explicitly dealing with the appropriate methodology for the study of complex phenomena. Next, we discuss the role of complexity in some of his theories. This exercise will demonstrate that Hayek constructs a worldview that progressively becomes more evolutionary and compatible with the CA.

After showing that the Austrians anticipated themes developed by the complexity approach to economics (or that the latter incorporated Austrian themes), we argue that the CA can be useful for discussing the controversy about the preponderance of (dis)equilibrating forces in the market process theory developed by the next generation of Austrian economists. After suggesting that the Austrians should pay more attention to the models developed by the CA, we conclude by arguing that the proponents of CA can also learn from a closer study of the Austrian School.

Complexity among the Austrians: from Menger to Mises.

Many of the characteristics found in the computational models of complexity science have been present in the Austrian school since its beginnings. The clearest example of this is given by the Mengerian theory of the evolution of money (Menger 1892). As agents realize that the acceptance of a liquid good as payment allows more advantageous exchanges, circumventing the need for a double coincidence of wants, the good becomes more liquid, which increases its value as a medium of exchange. This occurs until that good becomes the currency, without this having been planned by anyone.

Countering the accusation made in the Methodenstreit that economics ignores history and institutions, Menger's theory offers an explanation that is both theoretical (it uses, for instance, the hypothesis of self-interested agents) and accounts for the emergence and evolution in time of an institution, money. This explanation, an example of what is now called a network externality, includes both the phenomenon of path dependence, since different goods could become money, and the emergence of self-organization, obtained as a non-intentional consequence of the local interaction of agents during a learning process.

The presence of typical complexity themes in the beginning of the AS is not accidental. The main reason for this is as follows: while the other strands of the marginalist revolution, by adopting the mathematical formalism available at the time, were forced to ignore the themes developed by CA in their models, the Austrians, whose theories were expressed verbally, were free to discuss the matter. In fact, the formalization of economics during the twentieth century favored analyses involving aggregate variables related by equations whose simultaneous solution generated descriptions of equilibria, ignoring possible structural relationships between elements of such aggregates, while the methodological assumptions accepted by the Austrians did not reject verbal arguments for describing these relationships. This non-mathematical style of reasoning allowed Menger to use genetic-causal explanations rather than search for functional relationships between aggregate variables (Mayer 1995). This methodological choice is related to the consistent adherence to the principle of methodological individualism that we find in Menger. The same occurs in the work of Mises (1998), especially regarding the development of the Austrian theory of the market process, with its emphasis on entrepreneurial action out of equilibrium in an environment of uncertainty.

Features like uncertainty, learning, adaptability, and relationships between heterogeneous agents, fundamental to the understanding of real market phenomena, thus tended to disappear from formal neoclassical theory, though they survived in the Austrian tradition. We had to wait for the modern development of computational models that allow the formalization of some of these market characteristics so that the Austrians' themes could be revived—hence the similarity between the two approaches.

The inability to represent phenomena through aggregate variables, whose interest lies in their structure, is an example of the limitation of the formalism of the period and can be illustrated by the capital theory developed by Böhm-Bawerk (1959). The distinctive feature of this theory is the heterogeneity of capital. Production is represented by the author through continuous-imput/point-output processes, in which capital goods are transformed by the addition of other factors of production until they mature in the form of nondurable consumer goods. Capital is described as a structure whose elements are heterogeneous, since they are situated at different stages of the process. Increasing productivity through investment is associated with the adoption of an increasingly complex capital structure. Investment is not seen as obtaining more of the same equipment, but as the adoption of more specific capital goods, that fills the gaps in an increasingly differentiated structure.

Capital seen as a structure poses a number of interesting problems, since heterogeneity implies that changes in this structure, in a growth scenario or during economic cycles, cause production rigidities: time is needed for the capital structure to reorganize. The processes that occur during this transition period will be at the center of what has become Austrian macroeconomics, developed by Hayek. For our purposes, it suffices to note that certain phenomena, such as the distortions in this structure caused by different economic policies, cannot be studied by usual macroeconomic theory, given the degree of aggregation of its variables. Moreover, the difficulty in formally representing the capital structure is demonstrated by Böhm-Bawerk's failed attempt to use a scalar to measure a multidimensional structure - the average period of production.

The second reason for complexity becoming a common theme among the Austrians, especially in Mises and later in Hayek, is related to the opinions these authors held in policy debates. The classical Liberalism of the Austrians made their contributions to controversies emphasize those aspects of reality that were left out of the theoretical simplifications used as bases for the instruments of intervention proposed by their opponents. Both the ability to stabilize the economy with the use of macroeconomic policies and the possibility of central planning using the theory of general equilibrium -the latter suggested during the socialist economic calculation debate- were rejected because of the excessively aggregate character of macro theory and over static character of micro theory. As a result, the Austrians proposed theories that portray the economy as a self-organizing system whose complexity precludes the central control of its details.

Complexity in Hayek: methodological aspects.

Although we can identify, prior to Hayek, several similarities between the AS and CA, only in that author can we recognize a genuine forerunner of the modern study of complex systems. His theories progressively incorporate evolutionary elements and explicitly treat social phenomena as complex self-organizing systems, in contrast to the mechanistic models of the economy that prevailed in the twentieth century. Indeed, Hayek's concern with complex adaptive systems resulted in the clash between his theories and the research programs dominant in his era, as witnessed by the frequent debates in which the author was involved.

This is due in part to methodological peculiarities inherent to the study of complex phenomena, alien to the methodological canons inspired by the physical sciences professed by most economists. It is therefore natural that Hayek should address the methodological aspect of the study of complex phenomena, as we find in his The Theory of Complex Phenomena (Hayek 1967a).

In this text, Hayek begins his analysis with the identification of structures, called patterns, which show some regularity when taken as a whole, despite having elements that vary in each instance of the pattern. Science must then distinguish between predictions of specific settings for a particular pattern and predictions of general characteristics of the type of pattern. This distinction becomes crucial when the patterns are complex. Hayek defines complexity as "the minimum number of elements of which an instance of the pattern must consist in order to exhibit all the characteristic attributes of that class of patterns in question," (Hayek 1967a, p. 25) or "the minimum number of distinct variables a formula or model must possess in order to reproduce the characteristic patterns of structures of different fields (or to exhibit the general laws which these structures obey)" (Hayek 1967a, p. 26). Unlike classical physics, with its precise laws involving only a few variables, when we move to the biological and social phenomena, the degree of complexity necessarily increases. In such cases, it is impossible to observe all the initial conditions necessary to forecast particular configurations of complex patterns. It is impossible here to obtain the accuracy found in the study of simpler phenomena. However, it would still be possible to make pattern predictions of broader characteristics of the phenomenon.

The theories about these phenomena are seen by Hayek as "algebraic theories", since it is not possible, for the reason given above, to replace the variables of the model with observed data. These theories would then have lower empirical content than theories about simpler phenomena. Hayek (Hayek 1967a, p. 29) then defends a modified version of the philosophy of his friend Popper: although we should make theories as falsifiable as possible, the greater the complexity of the subject matter, the necessarily lower the degree of falsifiability of the theory. This is the price to pay for the study of complex phenomena.

The attempt to force the study of these patterns using the methodological standards of the physical sciences - what Hayek (1979) called "scientism" - prevents complex phenomena from being recognized as such. Statistics, for example, tends to eliminate complexity and treats the elements of a pattern as independent from each other, favoring homogeneous quantities and ignoring the connections and relative positions of the elements of the complex structure, which may be at the heart of the explanation of these phenomena.

The theory of evolution, Walrasian general equilibrium, and Chomsky′s linguistics are presented as examples of theories about complex phenomena. Just as the theory of evolution can explain the past but not predict details of the future, due to the profusion of unknown factors that affect the reproductive capacity of organisms, Walrasian theory should also be seen as an algebraic theory, which explains only some general principles about the economy's function instead of a usable tool for predicting specific values of the variables.

It is clear from these arguments that computational agent-based models are compatible with the methodology proposed by Hayek for the study of complex phenomena. These models circumvent the inability to obtain the infinite data concerning real complex patterns by creating artificial worlds in which we can investigate the structural relations between elements and, by repeating the simulations with diverse initial conditions, discern regularities and make pattern predictions about the behavior of these phenomena in the real world.

Complexity in Hayek: the coordination problem.

Hayek's methodological concern with complexity wasn′t just a passing interest, but a sign of the greater role that complexity plays in his theories. We can discern a theme throughout his work that unifies his theoretical system, having at its center the concept of complexity. This theme is defined by the search for explanations for the emergence of coordinated actions by individuals, whose limited knowledge precludes them from overcoming, by means of conscious control, the complexity of the problem of coordination.[3] This complexity, requiring a learning mechanism, will be present in several of the author's theories, as we shall see. From the beginning of his career until the early 1940s, Hayek (1935; 1939; 1941) developed the Austrian theory of capital and business cycles.[4] Although they don´t make explicit references to complexity, these theories treat macro-phenomena as complex, thus presenting the methodological peculiarities just discussed.

The Austrian theory of business cycles, the main rival of the Keynesian explanation for the economic crisis in the 1930s, soon fell into disrepute. One reason for this was methodological. The prevailing Positivism favored theories that employed variables with a high degree of aggregation and the absence of structural relations between components, so that they could be related by algebraic formulae and be empirically tested. Hayek, on the other hand, because of his belief that the correct macroeconomic explanation involved a higher degree of complexity, used structural relationships in place of aggregates and for that reason had to employ fewer operational concepts. As his theory allowed only some general pattern predictions, it could not be represented by an econometrically testable model.

In fact, his theory described the distortions of the capital structure resulting from changes in relative prices, which depended on the specific markets in which the monetary injections occurred (a local interaction the author called "Cantillon effect"). While economists in the twenties, using the aggregation level typical of the equation of exchange, saw no danger in increases in the money stock while this was offset by greater productivity that left the price level stable, Hayek considered money to be non-neutral even at a constant price level, given the distortions caused by relative prices changes.

The rejection of greater complexity implicit in this theory is confirmed by the nature of the controversies in which its author was involved. Repeating the debate between Clark and Böhm-Bawerk, Frank Knight criticized Hayek, denying the importance of the temporal dimension of capital. Hayek (1936) in turn criticized the Knightian conception of capital as a

3 In the same way, O'Driscoll (1977), identifies the problem of coordination as a central theme in the work of Hayek. Hayek himself, in the preface of this work, agrees with this characterization.

4 For a modern presentation of that theory, see Garrison (2000).

homogeneous fund that yields perpetual service. The temporal dimension in fact disappears in a steady state, where all stages of a production process are produced simultaneously; while on occasions that involve change, the temporal dimension of the structure of capital matters again, and thus capital cannot be represented as a homogeneous variable.

Further elaborating this theory, Hayek (1939) emphasizes the importance of the heterogeneity of capital. He criticizes, for example, the belief that investments always reduce the return on additional investment: if capital is heterogeneous, certain investments generate more demand for complementary investments, thereby increasing interest. It would be inappropriate to therefore assume a simple relationship between interest and investment without studying the morphology of capital. Kaldor (1942), on the other hand, considers changes in the capital structure over the cycle, –dubbed the "concertina effect"– to be empirically unimportant.

Besides these controversies, whose roots lie in the contrast between homogenous aggregates and concepts that describe structures, Hayek's (1941) attempt to develop the theory of capital in order to represent the complexity of its structure in richer form did not generate satisfactory results, testament to the difficulty of the task. This is an avenue of research on the AS that could be helped by the type of modeling used by the CA. Perhaps some aspects of the pattern of connections between the elements of the structure of capital could be represented as networks in computer models.

Disputes about business cycles and central planning led Hayek in the 1930s to investigate the meaning of equilibrium and competition. The result of this research was the development of a theory that, as we shall see, in many ways coincides with the characterization of markets made by the complexity approach to economics, so that the meaning of Arthur′s statement quoted at the beginning of this article can be readily understood.

In the first of a series of articles on the subject, Hayek (1937) exposes the need for a theory that explains the tendency toward equilibrium. The latter is defined as a situation in which the plans of all agents in a given period of time are mutually compatible. In equilibrium, each plan must contain correct information about the planned action of the others, which depends in part on the subjective expectations corresponding to the set of external facts. Unlike the plan of a single agent, whose elements are defined subjectively in his mind, the plans of several agents that interact will initially contain erroneous information about the behavior of others, in addition to divergent views on aspects of reality. The equilibrium theory seeks to circumvent the difficulty arising from the incompatibility of plans by supposing, through the assumption of perfect knowledge, that the data concerning the allocative problem are seen the same way by everyone. Thus, the question of the emergence of equilibrium, starting from an initial situation of discoordination, does not arise, and is reduced to a tautological problem of allocating given means to known ends.

Hayek, however, believes that economic theory is not a mere tautology, because empirically we observe some order and not chaos in markets, and for that reason there is a tendency toward equilibrium. To explain its emergence, we cannot avoid the task of determining under what conditions (and how) the subjective data approach (or not) underlying reality. A theory is then needed to explain how agents learn, to describe how their knowledge, initially divergent and erroneous, is corrected and spontaneously generates an organized order in a manner that could only be replicated consciously by some central organ possessing all information (Hayek 1937, p. 50). We thus reach the problem we call the unifying theme of Hayek's work, namely: to determine how to circumvent the limitation of knowledge in order to overcome the inherent complexity of the task of coordinating individual plans.

The answer to this problem involves the use of a mechanism that allows multiple actions and is subject to an error correction process. The learning process in Hayek's theory can thus be described as a mechanism of evolution by variation and selection,[5] as he detailed in later articles.

In one of those articles, Hayek (1945) shows that the problem of limited knowledge is solved with the help of the price system. This acts as a mechanism for the transmission of information that eliminates the need for knowledge of the details of the allocative problem. An agent does not need to know the various causes of the need to save some input, but he does so nevertheless due to the variations in prices. The revealed profitability of the projects induces corrections of knowledge and plans.

The adjustments, however, are not perfect (Hayek 1945, p. 527), and instead of an equilibrium we have only a tendency toward it. To understand the importance of the signaling role of prices out of equilibrium, it is important to emphasize the distinction that Hayek (1945, p. 521) makes between the scientific knowledge of the economists and the particular knowledge of the agent. The first is generic, shared by scientists, whereas the latter refers to the "particular circumstances of time and place" that

5 Up to this point, evolutionism is latent. Later, as we shall see, the evolutionary approach is explicit.

each individual faces. For Hayek, the latter type is relevant to the allocative problem. This dramatically increases the complexity of the coordination problem we face in markets. We must then explain how knowledge of the system's details, constantly changing, is transmitted via local interaction between agents. Or, in the words of the author, "… the economic problem of society is largely a problem of rapid adaptation to changes in the particular circumstances of time and place." (Hayek 1945, pg. 524)

The economic problem thus formulated brings us to the Hayekian critique of the theory of perfect competition (Hayek 1980 [1946]). This theory, by focusing exclusively on the final state of equilibrium, ignores the essential characteristics of the competitive process (Hayek 1980 [1946], p. 101), without which coordination in the market would not be possible. When activities commonly associated with competition by common sense—such as product variation, brand fidelity, advertising, or promotional pricing—are viewed with suspicion by the theory, certain policies that aim to increase competition by blocking these activities involve a *petition principii*. In the absence of the competitive rivalry between entrepreneurs, what is considered by the theory as given would not exist at all. In other words, if agents' knowledge is fallible, a trial and error learning mechanism is necessary, but this discovery procedure would be blocked by policies informed by a theory that assumes knowledge as given from the start.

"Competition as a discovery procedure" is exactly the title of the next article we will consider (Hayek 1978). In this article the author combines his theory of market process with the study of self-organizing systems, articulating his evolutionary approach. The definition of the fundamental problem of economics as the allocation of given means to known ends, compatible with a vision in which this problem could be solved consciously as an engineering problem is contrasted with the notion of spontaneous order (Hayek 1978, p. 258), according to which the emergence of coordination in the markets is not the result of the intention of any of its participants. The equilibrium concept, which implies that competition has ceased and knowledge is given, is replaced by the notion of order, which can be approximated even in an environment characterized by continuous change, by means of the negative feedback mechanism provided by the price system, which generates learning and partial compatibility of plans.[6]

In this learning process the emergence of novelty plays a central role. For Hayek, if data relative to the particular circumstances of time and place were indeed previously known, competition would be useless. Competi-

6 In this text, Hayek (p. 259) acknowledges Smith with his invisible hand metaphor as a precursor of the study of self-organizing systems.

tion is justified precisely because we do not know in advance the facts that determine the actions of competitors, i.e., to the extent that competition generates a discovery process.

A methodological consequence of this discussion is that, because it is impossible to determine what will be discovered by competitive process, the theory of competition should be limited to pattern prediction—the description of the more general aspects of learning processes, rather than predictions about particular instances of competition.

Another consequence concerns the assessment of market performance. Since it is impossible to anticipate the fruits of the discovery process, there is no way to operationalize an ex ante measure of performance. Additionally, the concept of Pareto optimality, applicable to states of equilibria, overlooks the discovery function of markets. Actual markets should thus be compared with other concrete institutional arrangements in terms of capacity, starting from an initial situation of relative ignorance, to generate learning and consequent adaptation to change, and should not be evaluated by a criterion that compares the real world with an unattainable abstract standard of perfect coordination, which assumes as given the knowledge that in fact results from the activity of competition out of equilibrium neglected by the theory.

The Hayekian characterization of the economy as a complex phenomenon, which emerges from the local interaction of individuals with fallible and local knowledge and that nevertheless results in some degree of coordination made possible by an error correction mechanism, invites the development of the study of the limits of human knowledge and also the investigation of the institutions that help to overcome these limits. Hayek's interests, from the 1950s onward, exceed the limits of pure economic theory, supplementing his understanding of the markets with theories about the evolution of institutions and psychological and philosophical theories about the nature of human knowledge. In these theories complex systems also occupy a leading role.[7]

Throughout the second half of his career, Hayek gives increasing importance to the notion of spontaneous order. In a work published in the same

7 Hayek (1976) is recognized as a pioneer of connectionist theory of mind. In this theory, mental phenomena are explained by the paths that impulses caused by sensory stimuli take in a network of nerve fibers. As with his other theories, here too Hayek describes a self-organizing system. The mind is seen as an emergent phenomenon, made from a material base, but which presents different characteristics from the elements of this base. The formation of an organized order is obtained through evolutionary processes. Again, the essence of the explanation involves relationships between structural elements that interact locally. This structure adapts as it comes into contact with external stimuli, involves a learning process, and emphasizes the limitations of knowledge.

year as his theory of mind, Hayek (1979, p. 70) uses as an example of this type of order the way forest trails are formed from individual decisions about which route to take. Each decision takes into account both the desired destination and the lower costs of using a path already cleared by previous travelers. The interaction between agents generates, through a feedback process, the formation of tracks that were not the intention of any particular agent. Phenomena of this nature, to the author, are frequent in social contexts[8], although relatively little studied from this point of view. Unlike trails or other physical and biological examples, complex patterns in economics are not observable, only their concrete elements: we can observe firms and individuals, but the coordination pattern resulting from their interaction forms an abstract order. Scientism, defined in the same book as the imitation in social sciences of positivism which is mistakenly believed to represent the method employed in the physical sciences, focuses only on what can be observed and measured, in this way limiting the recognition of spontaneous order in society, which is the subject of the Hayekian theory of institutional evolution, which we consider next (Hayek 1978b; 1982; 1988).

In this theory, just as in the theory of market process, abstract social orders are recognized by the compatibility of plans, i.e. the correspondence between expectations about the actions of agents and the actions actually performed (Hayek 1982, p. 36). Hayek classifies social orders into two types: those generated exogenously by the conscious creation of organizations, and those that emerge endogenously through evolutionary processes that result in spontaneous orders. In the latter category we have those fruits of human action but not of human design, such as language, social norms, and markets.

The first type, called taxis (Hayek 1982, p. 37), comprises simple and directly observable orders. Because they were created deliberately, they have specific purposes. The second type, cosmos, instead comprises usually complex and abstract orders that serve no specific purpose. For Hayek (1982, p.38), although spontaneous orders are not necessarily complex, only by this kind of order can one obtain structures with a high degree of complexity.

This brings us back to the author's central problem, the investigation of how to overcome the limitation of agents' knowledge in the face of the

8 Also in his work as a historian of ideas, Hayek rescues the notions of spontaneous order and evolution present in social sciences, particularly in the Scottish Enlightenment authors such as Smith, Mandeville, and Ferguson. Hayek (1967b) frequently borrows from Ferguson the phrase "the results of human action but not of human intention" to characterize the concept of spontaneous order in society.

complexity inherent to the task of coordinating their actions. Hayek's answer to this problem—which in the theory of market process consists of the study of how the price system helps to correct erroneous business assumptions—here is transformed into a generalized theory of learning by trial and error, belonging to the tradition known as evolutionary epistemology.[9] Hayek (1982, ch. 1), in tune with this tradition, distinguishes between constructivist (or Cartesian) rationalism and evolutionary rationalism, analogously to the Popperian distinction between naive and critical rationalism. Constructivist rationalism accepts as reasonable only what is demonstrable. When applied to the sphere of human action, it tends to legitimize only those social orders based on conscious control (taxis), rejecting the spontaneous orders (cosmos) as irrational. Evolutionary rationalism, on the other hand, believes that this position ignores the limitations of human knowledge. The demand for conscious control of social processes, because it considers only formal and abstract knowledge, excludes the use of agents' practical and local knowledge, thus drastically limiting the complexity of the order which can be obtained in this manner (Hayek 1982, p. 13). Additionally, Hayek (1988, p. 71) derives from evolutionary rationalism the conclusion that even formal knowledge cannot have its potential usefulness justified a priori, since its logical consequences cannot be completely anticipated. The program of constructivist rationalism would thus not be feasible, and true rationalism should take into account the consequences of the fallible and limited character of knowledge.

Historically, the growth in the use of knowledge in society has not depended on progressive conscious control, but on the evolution of rules and institutions that have generated, as an unintended consequence, processes of learning through error correction mechanisms, consistent with the fallible nature of knowledge.

The interaction of agents possessing limited knowledge in a complex environment then leads the author to consider—along with maximizing action—rule-based action, as the CA would later do. Hayek (1982, p.13) makes the case that most of the rules of conduct that guide human action, as well as the institutions that arise from the use of these rules, are adaptations to the impossibility of consciously taking into account all particular

9 Evolutionary epistemology, which includes among others the ideas of Popper and Hayek, emphasizes the fallible character of knowledge, identifying rationality with the use of mechanisms of learning by trial and error, in a fashion similar to natural selection in the theory of evolution. For an introduction, see Radnitzky and Bartley (1987). Hayek (1978b; 1982) develops a theory consistent with this doctrine, though only in his last book (Hayek 1988) do we find explicit references to it.

facts relevant to choice.

Hayek (1982, p. 44) noted, as modern students of complexity would later verify, that interactions under most conceivable types of rules do not result in orders or complex self-organized patterns. The adaptability of existing rules of action is then explained by the author as the result of an evolutionary process of selection of rules. Unsympathetic to sociobiology, Hayek emphasizes the differences between cultural and biological evolution. In the former, rules are transmitted culturally, not genetically inherited from parents. The fundamental difference, however, lies in the selective mechanism. Given the assumption of limited knowledge, the author does not believe that the best rules are imitated due to recognition of their usefulness: although conscious about its lack of plausibility in biological terms, Hayek (1982, p.18, p. 44; 1988, p. 25) believes that cultural evolution occurs largely through a kind of group selection: societies whose members have adopted certain rules tend to grow and displace other groups.

Although noting that certain rules are the result of spontaneous evolution and not planning, Hayek (1988, pp. 17-20) states that his evolutionism does not imply progress. In fact, the morality that evolved in tribal societies presupposes an agreement on the part of its members, about the objectives pursued and the means to get them, that it is inconsistent with the prevailing impersonal rules of interaction existing in modern societies, marked by a high degree division of labor. The persistence of this tribal morality is an example of dysfunctional evolutionary heritage.

Nor does recognition of their evolutionary origin imply that rules should necessarily be spontaneous (Hayek 1982, p. 45). Mankind can improve rules, and Hayek presented a set of institutional reform proposals along with his theory of social evolution. The spontaneous nature of the rules should not be confused with their ability to preserve spontaneous orders in society (Hayek 1982, p. 51). While general rules of conduct would be consistent with the abstract character of these orders, specific commands that prevent agents from using local knowledge based on their own decisions reduce their complexity. As in the theory of market process, here too freedom is advocated as a way to generate the diversity of actions necessary for the growth of fallible knowledge through a process of trial and error.

In this theory, once again, we find elements in common with the CA, especially the study of self-organization obtained through evolutionary processes for the interaction of rule-following individuals under limited rationality. From our brief examination of some of the theories developed by Hayek, we can conclude that complexity is a recurrent theme, for it occupies a central role in the research program of the author, whose main problem is to explain how the progressive complexity required for coordination of the activities of agents with limited knowledge is made possible by the adoption of mechanisms of learning by variation and error correction.

Hayek's difficulty in formally representing complex structures, so central to his thinking, explains how the modern CA in economics, when representing such structures in computer models, has revived various topics discussed by the Austrians. Nevertheless, subsequent generations of Austrian economists will not be part of the multidisciplinary effort that led to the consolidation of CA, partly due to the Austrian rejection of formal modeling. Still, the similarities between the two approaches remain, and as we will argue in the next section, there are certain insights pertaining to CA that could be used in a Neoaustrian theory of market process.

Complexity in Lachmann and Kirzner: the theory of market process.

The Misesian view of economics as the science of human action, together with the Hayekian analysis of equilibrium and competition, laid the foundation for the modern Austrian theory of market process developed by Lachmann and Kirzner.

Kirzner, like the modern students of complexity, does not assume the existence of equilibrium but rather seeks an explanation for its emergence. Using the Misesian notion of purposeful human action, Kirzner (1973) builds his theory of market process from the rejection of neoclassical notion of maximizing agents. In the Kirznerian view, the agent's structure of means and ends is not given, but its discovery is part of the problem faced by them. Kirzner thus posits the existence of another economic agent, the entrepreneur, whose function is the discovery of hitherto unnoticed exchange opportunities. These opportunities are not automatically realized and exploited in the market, but depend on the alertness of entrepreneurs who actively seek them.

Unlike neoclassical firms, which differ from each other only by the set of information they know, the Kirznerian entrepreneurs do not possess the same and correct model of the situation necessary to maximize expected profit. They must first, out of equilibrium, perceive profit opportunities; competition in a market depends on the rivalry between entrepreneurs that sets in motion a form of Hayekian discovery process, in which entrepreneurial activity plays an equilibrating role, because the knowledge of the agents gradually approaches the real economic fundamentals that define the profit opportunities if no further change occurs.

Lachmann, in turn, takes Hayek's work on learning and equilibrium as his starting point, but in the specific context of the Austrian theory of capital. Because in this theory production involves time, agents continually face plan revisions that must adapt the uses of the capital structure inherited from the past. Initially, Lachmann (1956) believed that those revised plans can become consistent with each other through the mechanism of error correction provided by the price system. In later works, however, Lachmann (1986) gradually abandoned this belief in the usefulness of the concept of equilibrium. As future knowledge cannot be anticipated in the present (Popper 1957), the future is necessarily uncertain and business expectations are never certain knowledge. Nevertheless, as he puts it, although the future cannot be known, it can be imagined. We therefore have different expectations held by different agents, expectations that guide individual plans and are a source of the continuous flux of novelties that prevent an equilibrium from being reached. The "radical subjectivism" of Lachmann, i.e. his belief in indeterminism generated by expectations, led the author to emphasize the creative aspect of competitive activity and criticize the vision of the market as a passive mechanism of adjustment to external changes.

The works of Kirzner and Lachmann gave rise to a controversy among the Austrians about the preponderance of equilibrating or disequilibrating forces in the market process. By emphasizing subjective elements, such as creative but fallible entrepreneurial knowledge, the Austrians were able to depart from the mechanistic model of competition offered by Neoclassical theory, treating the economy as out of equilibrium and showing the importance of diversity of opinions for competition to result in a process of error correction. But with the radical subjectivism and rejection of the notion of equilibrium, the Austrian tradition risked denying any regularity in the markets and thus falling into a kind of historicism. How could they avoid this?

The answer was given by Garrison (1982). For this author, the Austrian School should occupy an intermediate position between neoclassical theory, which treats the economy as if it were always in equilibrium, and radical subjectivism, which treats the economy as if equilibrium had no importance at all. What makes this intermediate position defensible is recognition of the existence of the underlying realities in the market process. By underlying realities, Garrison understands preferences, the individual endowments of goods, and availability of resources and technologies. The nexus between underlying realities and subjective actions occurs through a mechanism of selection of the latter in view of the existence of the former. Although such fundamentals do not determine the beliefs of agents, they serve as limitations.

As suggested by Garrison, the AS until now occupied an intermediate position between theories that treat human action as mechanical and predetermined on one side, or purely creative, without limitations imposed by the real world, on the other. How can the Austrian research program be advanced in this center oriented direction? We believe that a solution to this problem is offered by the affinities between the AS and CA, especially with regard to agent-based models that contain evolutionary learning processes. In these models we find a diversity of opinions and actions on the part of agents, and a mechanism that punishes mistakes and rewards opinions that make actions consistent with each other and with the economic fundamentals.

As we seek a balanced vision of the market process that encompasses both the subjectivism and indeterminism stressed by Lachmann and the error correction mechanism proposed by Kirzner, we could advance the Austrian theory of the market process. In evolutionary models of CA, the recognition of the realities underlying the market and the explicitation of a selection mechanism allow us to affirm the existence of equilibrating forces regardless of the accuracy of agents' knowledge. It is not enough to point to the fragility of this knowledge; equilibrating forces do not depend on certain knowledge. There may be order without omniscience, provided there is a mechanism, however imperfect, of error correction. The hypothesis that survives the process may not reliably represent reality, but at least those most inconsistent with the restrictions imposed by reality are eliminated.

Regarding the typical elements of the theory of evolution, Kirzner's work represents selection in the face of the underlying realities, while the work of Lachmann represents recombination and mutation, the variability of individual interpretations and actions. In our opinion, the evolutionary interpretation of AS allows a synthesis of the thought of Lachmann and Kirzner. If we join both in one evolutionary process, we can harness the positive aspects of both authors, avoiding their weaknesses.

The advantages of the rapprochement between Austrian and evolutionary thought were perceived by some authors familiar with the theory of the market process, such as Langlois (1994) and Witt (1992). Both advocate the adoption of evolutionary models of market process.[10] One of the challenges of this approach, as Witt noticed, is the difficulty of incorporating Austrian subjectivism into evolutionary models: these restrict a priori what may be devised by variation, so that the creative element stressed by Lachmann tends to be overlooked in these models, although this creativity appears in the form of mutations and recombinations of preprogrammed solutions. We will explore, in the final section, a concrete example of this difficulty in representing the creative element of the market process through the typical complexity models.

A Hayekian Critique of Complexity Models.

Having established the affinities between the CA and AS, we now consider a difference between them, arising from Hayek's methodological work on the study of complex phenomena. From that methodological point of view, agent-based computational models developed by the CA should be understood only as explanations of the general principles of operation of the phenomena studied, not their specific configurations. However, these models sometimes seem to be employed in a manner inconsistent with this methodological viewpoint.

Take, for example, the discussion of lock-in in inferior technologies. In models in which agents with bounded rationality learn by trial and error—groping in their neighborhood in an n-dimensional space of possibilities, with every move in this neighborhood evaluated by its performance (fitness)—it is possible that, depending on the starting point, the learning process may lock us into a solution that is just a local maximum in the fitness surface, preventing the efficient equilibrium from being reached. David (1985) believes that this can be illustrated by the QWERTY layout standard on keyboards, used instead of the more efficient Dvorak system. The first standard was an adaptive solution in the era of mechanical typewriters, but with the advent of electric machines and later computers, the technical reason that justified the strange configuration of letters is no longer present, yet we are still stuck with the inferior solution, given the costs of learning a new configuration. In this case, market competition does not lead us to the optimal outcome.

We argue that this use of the model brings the CA nearer to Neoclassical

10 Langlois, for instance, writes: "What all this suggests, of course, is that one must begin to theorize in explicitly evolutionary terms rather than to rely on optimization models as a "summary" of the results of the evolutionary process." (Langlois 1994, p.34).

economics, with its exclusive focus on Pareto efficiency, and pushes us away from the interest in adaptability found in both the CA in general and the Austrians. In fact, in Biology it is recognized that artificial selection in models is different from natural selection in nature. It is argued that evolution in the real world is hardly locked into a local maximum, if we consider other variables present in natural selection that are disregarded by the model. What may be a peak in one dimension of the fitness surface can be a gentle slope if we consider other dimensions, so that evolution can continue along another hillside (Ridley 1996, p. 219). Likewise, for the Austrians, a seemingly unassailable monopoly is rarely challenged by a firm that exactly replicates its activity: competition, seen as a process of discovery, is manifested through solutions that were not previously imagined. Of course we never are in the best possible world —we would make different decisions if the past were different, but the Austrians are very skeptical about the ability of modelers and planners to ascertain which alternatives are better in a competitive system, whereas entrepreneurs have the liberty to test their opinions.

The difference between the two positions is of a methodological nature: a formal model determines and therefore limits what can be experienced. If the model is interpreted literally, one can easily conclude that evolution will cease. But, interpreted as something that simply shows the general principles of the workings of a learning mechanism, we can appreciate the ability of this mechanism to generate innovations. The first interpretation would only be realistic if the selective criteria were actually known in advance. That would happen if those criteria were consciously imposed, as in a hierarchical order (Hayekian taxis). But in a spontaneous order, such as the market, in which the profitability of a product depends on the evaluation of several consumers, the variables taken into account by these consumers are multiple, so that we cannot enumerate them a priori. As nobody could specify all the aspects of a product that may influence the choice of consumers, the scope for entrepreneurial novelty is greater than what can be modeled.

This difference is clear among biologists, who carefully distinguish between natural selection and artificial selection models. Dawkins (1997), in fact, argues that models that simulate natural selection by using genetic algorithms employ parameters that are necessarily arbitrary. The only purpose of the model is to illustrate the principle of operation of the process, the complexity of which is much larger in nature. In nature, new solutions emerge that would never arise in the artificial selection model, because the dimensions that define what can be tried are not restricted a priori.

Complexity Approach economists should pay attention to these methodological considerations, since the representation of a theory through formal models that specify what can be taken into account by agents generates a tendency to model learning as an inductive process (Arthur 1994). In inductive learning, agents already know the model that correctly represents the structure of the world, differing only in their command of the sets of information that feed the model. This hinders the capability of market competition analysis to appreciate the importance of creativity, the discovery mechanism emphasized by Hayek, and paradoxically, the very complexity inherent in economic phenomena.

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