Hayek's Theory on Complexity and Knowledge. Dichotomies, Levels of Analysis, and Bounded Rationality

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Abstract. Hayek maintains that models of complexity must consider two closely interrelated factors: the large number of variables and the connections among them. These two conditions, which define complex phenomena, exhibit a different logical dimension. The former (the "large number of variables") describes complexity in quantitative (numerical) terms; the latter provides a view of complex phenomena in logical-relational terms, and it is evoked to explain the emergent properties of the whole. Despite the close relation between these concepts, the first notion essentially prevails over the latter, delineating a distinctive configuration of the theory. This perspective also emerges when Hayek defines "dispersed" and "inarticulate" knowledge, and introduces the concept of the "explanations of the principles". Finally, the notion of level of analysis is discussed in order to interpret Hayek's two concepts which define complexity.

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Introduction

In recent years various essays have been devoted to Hayek's theory of complexity. They have focused on the close connection between his analysis of complex phenomena and market evolutionary theory (Vaughn, 1999; see also Weimer, 1982; Chaumont-Chandelier,1999; Wible 2000, Gaus, 2007). It has also been argued that Hayek's theory shares many features with contemporary studies on complexity. In both approaches, self-organization of individuals units, adaptation processes, non-linearity, and path dependency connote complex systems whose (emergent) properties cannot be reduced to those of their parts (Vaughn, 1999). Yet it has been observed that Hayek's "invisible hand" perspective conflicts with both inefficiency linked to "lock-in" effects determined by the technological path, and theories on complex adaptive behaviours which do not trust in the benevolent forces of the market (Kilpatrick, 2001).

In general, Hayek's spontaneous, evolutionary, order and complex phenomena theories are interpreted as coherent parts of a homogeneous approach. This is correct, although Hayek dealt in some essays with "complex phenomena" as exhibiting distinctive epistemological features in some respects independent from the spontaneous order thesis (which appeared later than some of his epistemological contributions).[1] Hence, the following analysis describes Hayek's specific analysis on complexity, and subsequently shows how it is connected to other parts of his theoretical apparatus.

Especially in those essays (but also in other parts of his work), Hayek maintains that models of complexity consider two closely interwoven factors: a large number of variables, and the connections among them which generate the properties of a (complex) phenomenon. Over time, Hayek used this pattern to explain many events, from the appearance of spontaneous order to the nature of knowledge in market societies. A third element in Hayek's view of complexity should be considered: the heterogeneity of systems' constituents.[2] Yet, this latter characteristic is less general in nature, so to speak, than the other two. In fact, it is evident in social systems, whose members are individuals, whilst it has an unclear function when it concerns the components of different, complex, systems (for example, the biological world; see section 1).

The thesis put forward in this paper is that the two basic conditions which, according to Hayek, define complex phenomena (number of variables and their interconnections), firstly exhibit a different logical dimension; and secondly are such that the former tacitly prevails over the latter as the explanatory term. As a consequence, the unitary explanation of complexity, based on the simple co-occurrence of the two categories, fails to hold. More precisely, I shall seek to show how this dualistic vision (*co-occurrence* of the two features of complexity vs. *prevalence* of one of them) permeates Hayek's work. In general, the criterion based on the (large or small) number of variables is a descriptive term - in the sense that it is the criterion that

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[1] Some elements of Hayek's theory of complexity were put forward in the 1940s and later converged (and were harmonized) with spontaneous orders theory. Caldwell (2001, p. 7) observes that some evolutionary themes appeared (relatively late) in *The Constitution of Liberty* (1960).

[2] I thank one of the referees for having suggested consideration of this topic.

Hayek adopts to distinguish between simple and complex phenomena (see Barry, 1979, p. 28) - while the nature of connections among the variables evokes a different dimension (definable as *logical-relational*) in some way able to explain how the properties of the whole arise. Hayek does not consider this distinction, because these categories are in most cases *indisputably connected*. This circumstance is somehow considered in contemporary theories of complexity which often stress the many interacting (heterogeneous) agents which constitute the basic conditions for complex problems. By contrast, Hayek's idea that models of *simple phenomena* are *always* characterized by a small number of variables is dubious, given that large numbers of variables appear even in very elementary structures.[3] In this sense, the paper examines the theoretical consequences of Hayek's thesis, and specifically how the representation of complexity changes when he emphasizes one term more than the other.

In what follows (section 1), I discuss how Hayek explains the role of the large number of variables and of the manners of their connection, when he treats the distinction between the physical and social (and biological) sciences, and between complex and simple phenomena. The former category describes complexity in terms of numerical, interrelated, events; the latter provides a view of complex phenomena in logical-relational terms, and it is evoked to explain the emergent properties of the whole. Despite the close relation between these concepts, the former essentially prevails over the latter, delineating the distinctive configuration of Hayek's theory.

Section 2 shows how the *numerical* concept of complexity induces Hayek to describe complex systems *as if they were* objective events, although his subjectivism indisputably distinguishes between external reality and its mental reconstruction. Sections 2.1 refers to Herbert A. Simon's work and discusses how the *level of analysis*

[3] There is no agreement in contemporary studies on the notion of complexity (Horgan, 1997, p. 303, footnote 11; Rosser, 1999). For example, Grobstein (1973) and Pattee (1973) focus on the nature of relationships among the components of a given level of a (complex) order, independently of their number. Similarly, Arthur does not mention the number of variables as a condition for modelling complexity, while he stresses the relational component: "Complex studies look at interacting elements producing aggregate patterns that those elements in turn react to. This seems to be the theme of all studies I've seen on complexity" (Arthur, 2005, pp. 20-21). Yet, following Holland (1988, p. 117), Arthur, Durlauf and Lane (1997, p. 3) maintain: "What happens in the economy is determined

adopted is crucial for defining complexity, in that it determines what variables are relevant (and what number of them must be considered). In this perspective, *the number of variables is one condition included in the model*, but it does not constitute, as it does for Hayek, the primary basis on which to elaborate an explanation of complex phenomena.

Section 3 treats the notion of "dispersed knowledge" (or more appropriately *dispersed information*) used to describe market complexity and which defines knowledge in *quantitative and/or informational* terms. This is an empirical variant of the numerical approach to complex phenomena, according to which the market is complex because the enormous amount of information possessed by individuals is fragmented. Yet this concept does not *per se* explain how dispersed information contributes to the emergence of a spontaneous order. It implies an empirical-descriptive level of analysis, while the self-organizing properties of the market involve a different, explanatory, category, and a different logical level of analysis. This latter perspective stresses that the market is not complex because of the dispersion of an infinite amount of information; rather, it is complex because it is a mechanism (a system of rules) able to propagate fragmented information, thus generating a spontaneous order. Its complexity therefore derives from this capacity.

The case of "inarticulate knowledge" (dealt with in section 4) is very different. It is not measurable, nor does it involve a large amount of "particular facts" as "dispersed knowledge" does. It is a part of (and arises from) tacit mental processes involving schemes of thought (abstract rules) which guide our behaviour. The complexity of this knowledge does not depend on its size but instead derives from cognitive mechanisms which enable the use of unconscious capacities to discover new opportunities and obey abstract rules on which spontaneous order depends.

Finally, section 5 shows how the same dualism is apparent when Hayek deals with "explanations of the principle". On the one hand, these are viewed as the consequence of the impossibility of knowing an excessively large number of facts. On the other

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by the interaction of many dispersed, possibly heterogeneous, agents acting in parallel". The latter point has also been emphasized by, among others, Markose (2005), and Foley (2003, p. 2).

hand, they are conceived as able to represent the changeable relations among the components of a (social, mental, or biological) structure from which emergent properties and complex phenomena arise in evolutionary terms.

1. Hayek's theory of complexity

As is well-known, in *Scientism* (1942-1944) Hayek defines the method of social sciences in subjectivist terms: that is, he maintains that human action depends on the perception, interpretation, and classification of the external world. The social sciences must therefore start from this assumption, since "things *are* what the acting people think they are" (Hayek, (1979 [1942-1944], p. 44). This perspective delineates the difference between the approaches of the natural and social sciences, where the former is "objective" and the latter "subjective" (Hayek, (1979 [1942-1944], p. 46). This requires drawing a clear distinction between the (opposite) methods of the two kinds of science, showing the non-applicability of the tools of physics to the social sciences. The natural sciences adopt a deductive or "analytic" procedure whereby they move from wholes to their particular elements, while the social sciences (which treat "complex phenomena") adopt a "compositive" method whereby the whole is reproduced and explained starting from its individual elements (Hayek, 1979 [1942-1944], pp. 65-67); see Hayek, 1935a, pp. 126-127).

Other differences become apparent on considering the aims of the natural and social scientist: the former (an "astronomer") seeks to know "*all the elements* of which his universe is composed", whereas the latter can only know "the *types of elements*" of his universe because he is faced by a too large "number of separate variables". This requires the social sciences to use a distinctive form of knowledge: "knowledge of the principle" which generates social phenomena whose abstract nature does not permit prediction of the precise outcomes of social processes (Hayek, 1979 [1942-1944], pp. 73-74).

In *Degrees of Explanation* (1955), Hayek provides further details on the differences between the natural sciences (specifically physics) and the social sciences with respect to their methods and objects.

> "More particularly, what we regard as the field of physics may well be totally of phenomena where the *number of significantly connected variables of different kind*s *is sufficiently small* to enable us to study them as if they formed a *closed system* for which we can observe and control all the determining factors" (1967 [1955], pp. 3-4; emphasis added; cf. p. 20)

Physics, as a science which treats "relatively simple" phenomena, is concerned with "closed systems" whose "few connected events" allow their close control, whilst social systems are (implicitly) open systems comprising a large number of interrelated elements. These characteristics make it possible to distinguish between simple and complex phenomena. Sometimes not even physics is able to produce exact predictions owing to limitations in the precision of measurement. Biology is the discipline (among the natural sciences) which essentially resorts to "explanation of the principle" because the theory of evolution does not yield specific predictions but "can explain only *kinds* of phenomena, defined by very general characteristics" (Hayek, 1967 [1955], p. 13; cf. 1967 [1964], p. 31). [4]

In *The Theory of Complex Phenomena* (1964) Hayek reiterates his conviction that the physical sciences treat "simple phenomena", while social (biological and mind) theories deal with "complex phenomena". Moreover, as in previous essays, he has complexity depend on the number of variables in the system. This is evident when one compares "inanimate" (i.e., physical) and "animate" worlds (including the social universe). The latter are more complex and "more highly organized", and moving from one to another implies observation of an "increasing complexity" (Hayek, 1967 [1964], p. 26). In fact, Hayek later maintained, the difference between simple and complex phenomena "is certainly one of degree", and he specified: "I think *the essential point is*

[4] Also cybernetics, theory of automata, general system theory, communication theory, and linguistics treat complex phenomena, and seem to rely on this explanatory method (Hayek, 1967 [1955], p. 20; 1967a, p. 72; 1979, pp. 158-159).

that degree of complexity of phenomena is measured by the number of variables that an explanatory theory must contain" (Hayek, 1982, p. 321; emphasis added). Therefore, assuming the criterion of the "number of distinct variables" in creating a model, "Non-physical phenomena are more complex because we call physical what can be described by relatively simple formulae" (Hayek, 1967 [1964], p. 26)[5].

With respect to *Degrees of Explanation*, it is misleading to wonder whether structures are "open" or "closed", since there are no closed systems in the universe; rather, the focus is on the large number of variables which should be included in models of complexity (Hayek, 1967 [1964], p. 27). In this regard, statistics cannot provide a solution for complexity problems because, although it treats large numbers, it eliminates complexity itself by dealing with "the individual elements which it counts as if they were not systematically connected" (Hayek, 1967 [1964], p. 29).[6] Moreover, models of complexity must consider the change over time of interactions among a large number of variables when they belong to an evolutionary system. By contrast, models for simple systems treat a small number of connected variables, and their ability to provide exact predictions depends on whether they can measure and empirically control the data which specifically represent those variables.

Finally, these opinions are summarized, once again, in *The Pretence of Knowledge* (1975), where Hayek maintains that

1) the physical sciences, contrary to economics and other disciplines, do not treat complex phenomena (Hayek, 1978 [1975], p. 24). In particular, the physical sciences assume that "any important factor which determines the observed events will itself be directly *observable and measurable*", whilst complex

[5] According to Caldwell, "a striking difference is evident" from *Scientism* to *Degrees*, since "the dividing line is not between the natural and social sciences, but between those that study relatively simple versus complex phenomena" (Caldwell, 2000, p. 11). Yet the basic criterion of "number of separate variables" by which to divide the two kinds of sciences, and their objects of analysis, permeates both the articles.

[6] Physics resorts to "statistics to deal with systems of very large numbers of variables" and statistical technique is "a manner of reducing the number of separate entities, connected by laws which have to be stated, *to comparatively few* […] and not a technique for dealing with the *interplay of a large number of such significantly independent variables as the individuals in a social order*." (Hayek, 1967 [1955], p. 3, note 1; emphasis added; cf. pp. 8-9).

phenomena like the market "*will hardly ever be fully known or measurable*" (Hayek, 1978 [1975], p. 24; emphasis added).

2) the social sciences and biology deal with "structures of *essential* complexity" connoted by a "relatively large numbers of variables". In particular, in the economic sphere, competition involves "a fairly large number of acting persons" (Hayek, 1978 [1975], p. 26).
3) the social sciences deal with "phenomena of organized complexity", that is, "the character of the structures showing it [the organized complexity] depends not only on the properties of the individual elements of which they are composed, and the relative frequency with which they occur, but *also on the manner in which the individual elements are connected with each other*" (Hayek, 1978 [1975], pp. 26-27; emphasis added).

The third point makes it possible to view "organized complexity" in terms of a whole, with its own properties. A complex structure, with reference to the mind, implies that "a particular order of events or objects is something different from all the individual events taken separately" (Hayek, 1976 [1952], p. 47), and its properties emerge from the *peculiar connection* of its individual parts. Therefore, the view according to which "An order involves elements *plus* certain relations between them" (Hayek, 1976 [1952], p. 47; can be assumed as a general perspective from which to define many complex structures, from the mind to the market.

In short, Hayek defines complexity on the basis of two concepts – number of variables and the modes of their connection – which perform different roles. A third characteristic – which is not specifically mentioned by Hayek in his methodological essays but is widely present in his work as a whole – should be considered: the heterogeneity of agents, who exhibit different histories, behaviours, cognitive processes and knowledge (see sections 3 and 4). This is an important feature when the complex phenomenon is society and its constituents are individuals. By contrast, it is a less obvious concept when Hayek relates complexity to other fields, for example biological systems, whose members are living beings which do not possess those human characteristics (see note 4 and section 5). Then, if we consider cybernetics, mind,

automata, and communication theories, which Hayek alludes to as examples of complexity theories, the notion of the heterogeneity of individual constituents is more problematic. I therefore consider only the number of variables and their relations as the more general terms which explicitly connote Hayek's view of complexity. The former is a condition for the model to which correspond *potentially* "observable and measurable" events which characterize complex phenomena in the external world (notwithstanding the great difficulty of knowing them in their entirety), whilst the latter is an explanatory (logical-relational) category. Yet, in this context, the Hayekian logical-relational term is somewhat theoretically weak. In fact, its distinctive feature (the connection among variables) *is a characteristic shared by both simple and complex phenomena*, whereas the former are connoted by small number, and the latter are defined by a large number of interrelated variables, and the move from the one to the other is only matter of degree (Hayek, 1982, p. 321). Therefore, the *numerical* approach prevails over the *logical-relational* one in defining complexity. Moreover, in general, a small number of facts permit the observability, measurability, manipulability, and predictability of (future) sets of connected events, which for these reasons are simple. The reverse outcomes connote large number of related events, which consequently determine the nature of complexity. Nonetheless the logical-relational perspective, which points out what principles explain the emergence of organized structures, is present in Hayek's discourse (Hayek, 1973, p. 38).

Using Hayek's vocabulary, it seems that emergent properties, which, for example, connote elementary living systems, can be explained by showing how "the individual elements are connected with each other", whilst their number does not say much about the functioning of those systems. Yet proceeding from inanimate to animate and social phenomena, from low to high levels of complexity,[7] implies conceiving complexity predominantly as a matter of degree – as Hayek himself maintained. If this is so, then phenomena considered between those opposite extremes exhibit the same, qualitative, nature, since there is a fundamental *continuity* among them, whilst their difference is

[7] Assuming, of course, the criterion of "the minimum number of distinct variables a formula or model must possess in order to reproduce" complexity (Hayek, 1967 [1964], p. 26).

specified only in quantitative terms. By contrast, the emphasis on changeable connections among elements gives rise to a different (*logical*) category able to show, in intuitive terms, the emergent properties of living and social systems, as well as their *discontinuity* with respect to the inanimate (relatively uncomplex) world (see Parisi, 1992, pp. 256-257). From *this* perspective, the explanation of complexity and its properties focuses more on the network of relations among variables than on their number, where this latter is only one condition for the model.[8]

In *The Pretence of Knowledge*, Hayek refers to Warren Weaver's opposition between "phenomena of unorganized complexity" (limited to "some fields" of physics) and the "phenomena of organized complexity" (Hayek, 1978 [1975], p. 26) dealt with by the social sciences. "Complexity" *characterizes both situations*, so that the task of science seems to be *explaining the organization*, that is, understanding *why some complex phenomena are organized but others are not*. This requires furnishing a logical category able to explain the discontinuity between non-organization and organization. More precisely, Hayek admits that there are *two kinds of complexity*: "organized" and "unorganized", so that the problem is not the number of variables (which is indefinite in both situations) but rather discovering the reasons that induce certain types of complexity to become "organized".[9] But then, a few pages later, he states: "A theory of essentially complex phenomena must refer to a large number of particular facts" (Hayek, 1978 [1975], p. 32), thereby reintroducing the distinction between the opposite couples of simple events/few variables, and complexity/large number of variables.

In conclusion, Hayek examines neither the theoretical differences between the two categories that he uses to *define* complexity (number of variables and the modes of

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[8] Vaughn observes that Hayek's focus on the number of variables does not describe the characteristics of modern complex systems, although he captures them by introducing the non-linearity of elements, and their path-dependent interaction (Vaughn, 1999, p. 249; cf. Gaus 2007). Although this is correct, the number of variables nonetheless is an essential part of Hayek's definition of complex phenomena, and it determines his approach to the problem.

[9] On the other hand, Weaver (1948, p. 538) points out that problems of "disorganized complexity" (similarly to those of "organized complexity") involve a very large number of variables. Therefore they do not coincide with those implied in Hayek's models for simple phenomena, which are connoted by small numbers of variables.

their relations) – which are constantly connected in his work – nor, evidently, the consequences of their distinction. He therefore essentially describes complex and non-complex phenomena in sharp, dichotomic, terms and specifies which disciplines and methods deal with them, as listed below:

COMPLEX PHENOMENA	NON-COMPLEX PHENOMENA
- Social science, evolutionary biology (and cybernetic, mind, automata, general system, and communication theories)	- Physics (and statistics)
- "compositive" ("synthetic") method	- deductive ("analytic") method
- large number of connected variables	- small number of connected variables
- non-measurable variables	- measurable variables
- types of relations among variables which produce complexity	- types of relations among variables which do not produce complexity
- explanations of the principle (unpredictability)	- exact prediction of particular events (predictability)
- agents' heterogeneity (social order)	

2. Complexity and number of variables: objective and subjective representations

Hayek's emphasis on the role of a large number of connected variables induces a *description* of complex systems *as if they were* objective events (i.e., *as if they were* describable in purely objective terms). In the *simple* world delineated by physics, facts are "observable and measurable", whilst in the universe represented by evolutionary biology and by the social sciences they are not, because they are "too numerous". That is to say, they objectively exist as "particular facts" but cannot be fully observed over time by scholars, with the consequence that the latter are forced to consider "types of elements" (Hayek, 1973, pp. 23-24).

This account should be considered in connection with Hayek's subjectivism. In fact, what appears as an objective event is the *result* of a subjective reconstruction of the whole which at a different level is also accomplished by theories (Hayek, 1979 [1942-1944], pp. 82-83; see Weimer, 1982, p. 250): individuals select large numbers of objects as components of the same class of events, and this selection derives from their subjective classification of the external world (Hayek, 1979 [1942-1944], p. 80).[10]

However, the *perception* of a huge number of related events, to which correspond a huge number of data, seems to produce a perception of the environment as complex. For example, this view implicitly appears in Hayek's contributions to the socialist calculation debate, where he points out the planner's difficulty in processing (and knowing) the infinite number of data (the "amount of concrete information") dispersed in the economic system (Hayek, 1935b, pp. 153-154). This is a problem described in terms of objective complexity, although the latter was probably not conceived in subjective terms in 1935, because Hayek elaborated his mature view on subjectivism only later (Caldwell, 2003, pp. 216-217). In short, it seems that the planner's difficulty would be shared (and perceived) in a similar way by any other person in the same position, individual differences notwithstanding. As a consequence, the *numerical* criterion, so to speak, seems to be a suitable instrument with which to define (and perceive) complexity. However, the matter is not so straightforward if one re-analyzes it considering what Hayek defines as simple events, as opposed to complex ones. Simon's perspective sheds light on these matters.

2.1 Simon: complexity, levels of analysis, and bounded rationality

According to Simon, external complexity influences the individual's "internal representation" of the environment; and when this latter is coupled with a problem or

[10] This account has been viewed as problematic. For example, according to Lawson, especially in *Scientism*, Hayek "does not so much escape the characteristic errors of positivism as reproduce them in a subjectivist form", and in general "he fails in formulating his subjectivist alternative to transcend many of the errors of positivism […] That is, in parallel with the positivist reduction of physical reality to experience, Hayek succeeds only in reducing human society to conceptions" (Lawson, 1997, pp. 145 and 150).

goal, a "task environment" arises (Newell and Simon, 1972; 1981). Complexity exists in the objective world, and it stimulates adaptive responses by computationally limited beings: the ant's irregular path is due to the complexity of the surface of the beach, to which it adapts its behaviour, given its limited (rational) capacities, although for a human observer more linear behaviours are possible (Simon, 1996 [1969], pp. 51-53). This perspective is generalized to humans[11] and shows that very simple situations can be perceived as complex if agents' computational systems do not permit mastery of them (as happens to the ant). Hence, the large (or small) number of real data – in absolute terms – is not *per se* a fundamental argument for defining complexity (or its absence). Rather, rationally limited individuals, starting from their internal representation of the environment, cope with a problem by adopting simplifying strategies (heuristic processes) for its solution (where the number of variables treated depend on the particular circumstances of that context).

As a consequence, events that Hayek qualifies as *simple* (like organizations[12], "small groups of primitive society"[13], or an imaginary planning, whose conditions were "so simple that a single person or board could effectively survey all the relevant facts" (Hayek, 1997 [1944], p. 36))[14] can be viewed as *complex* for Simon's agents. In particular, according to Simon, and contrary to Hayek, organizations exhibit high levels of complexity which cannot normally be mastered by the organizer's bounded rationality, since, within organizations, "the 'real' situation is almost always far too complex to be handled in detail" (March and Simon 1993 [1958], p. 171).

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[11] "The apparent complexity of behavior[s] [by ants and men] over time is largely a reflection of the complexity of the environment in which [they] they find [themselves]" (Simon, 1996 [1969], pp. 52-53).

[12] If the "limited resources" of an organization are known to the organizer, they can be managed, and organization is not a complex system (Hayek, 1978 [1968a], p. 76).

[13] In these societies "the concrete events which individuals encounter in their daily pursuits will be very much the same for all, and they will act together because the events they know and the objectives at which they aim are more or less the same". This situation is to the reverse of the complexity of Great Society, "where millions of men interact" (Hayek, 1973, p. 14). Once again, large and small numbers matter in defining complex and simple systems.

[14] Therefore, small numbers of variables define simple circumstances, while large numbers define complex ones. In fact, Hayek immediately specifies: "It is only as the factors which have to be taken into account become so numerous that is impossible to gain a synoptic view of them" (Hayek, 1997 [1944], p. 36).

Simon points out another crucial element, this one linked to his Kantian opinion that the external world cannot be known in itself but only internally represented[15]: "How complex or simple a structure is depends critically upon the way we describe it" (Simon, 1962, p. 481). As a consequence, a description (or model) of complexity depends on the *level of analysis* adopted, and this determines the number of variables considered. If this level changes, so too do the variables included in the model, and their (large or small) number reflects this circumstance. Moreover, many levels of analysis and their reciprocal interactions must be evaluated in many circumstances, so that the number of variables may be very large. Yet this is not a barrier against an inquiry into complexity. The argument of interrelations among different levels of analysis leads to the core of Simon's theory of complexity, which is based on the notions of "hierarchy" and "near decomposability".

> "By a *hierarchic system*, or hierarchy, I mean a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem. In most systems in nature, it is somewhat arbitrary as to where we leave off the partitioning, and what subsystems we take as elementary." (Simon, 1962, p. 468)

In short, the level of analysis *decides* what an "elementary subsystem" is (and what variables are included in the model representing it), and this is "somewhat arbitrary". Consideration of the number of variables, in absolute terms, is not the correct approach, because it may generate an infinite regression as the search for the most elementary structure proceeds; whereas, I repeat, whether a phenomenon is complex or simple (elementary) depends on the unit of analysis.[16] In fact, Simon maintains, some decades ago atoms

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[15] See Newell and Simon (1972, pp. 56 and 824).

[16] "*Scientific knowledge is organized in levels*, not because reduction in principle is impossible, but because nature is organized in levels, and the pattern of each level is most clearly discerned by abstracting from the detail of the levels far below" (Simon, 1977, pp. 260-261; emphasis added).

"were elementary particles; today, to the nuclear physicist, they are complex systems. For certain purposes of astronomy, whole stars, or even galaxies, can be regarded as elementary subsystems. In one kind of biological research, a cell may be treated as an elementary subsystem; in another, a protein molecule; in still another, an amino acid residue." (Simon, 1962, p. 468)

The level of analysis matters when one observes the relation between subsystems and the aggregate. The near decomposability of hierarchic systems implies the distinction "between the interactions *among* subsystems, on the one hand, and the interactions *within* subsystems – i.e., among the parts of those subsystems – on the other" (Simon, 1962, p. 473). This means that *nearly decomposable* structures are characterized by "interactions among the subsystems [which] are weak, but not negligible", and in the short run the behaviour of each element in a system is approximately independent, while in the long run it depends in "an aggregate way" on the behaviour of the other components (Simon, 1962, p. 474).[17]

Once again, the unit of analysis adopted is fundamental with respect to the number of variables included in the model, which change according to whether the focus is on interaction among or within subsystems.[18]

Summarizing, for Hayek the number of variables seems to be largely classified by individuals (and scientists) in the same way, in the sense that in general terms their perception of reality is *sufficiently* homogeneous, although "the knowledge and beliefs of different people" can be "different and often conflicting in many respects" (Hayek, 1979 [1942-1944], pp. 49-50; cf. p. 80). On the other hand, cultural selection processes enable individuals to share general rules of conduct which refer to similar "schemata of

[17] These characteristics are illustrated by the example of a building with thermal insulation against the external environment. The building is divided into a certain number of rooms (the subsystems), the walls of which constitute the boundaries of the main subsystems, and in turn each room is divided into cubicles with poor insulation. The initial, wide, thermal difference among the cubicles, and from room to room will gradually disappear; in particular it will be reduced first among the cubicles, and subsequently among rooms (Simon, 1962, p. 474).

[18] Note that, Simon, when discussing the role of levels of analysis, observes that the interrelated subsystems are "intermediate stable forms" which strongly influence the evolution of complex aggregates, since they act as building blocks for further construction (Simon, 1962; 2000). Both Holland (1988, p. 118) and Arthur, Durlauf and Lane (1997, p. 4), using the same words, accept these ideas as indicating one feature of complex systems: "The economy has many levels of

thought"; it is consequently likely that they elaborate shared representations of (social) reality (see Caldwell, 2003, p. 286). It is therefore unsurprising that large numbers of related events are codified as complex phenomena, whilst small numbers of (connected) particular facts assume the form of simple, tractable, phenomena. But in Simon's perspective this view cannot be held, because complexity cannot be treated by assuming Hayek's large/small number of variables dichotomy as the reference point, since the number of variables matters in relation to the unit of analysis adopted. Moreover, it should be borne in mind that Hayek's view on the role of number of variables essentially refers to the impossibility of observing, measuring, controlling, and exactly predicting a given phenomenon. This impossibility derives from "our irremediable ignorance of most of the particular facts which determine the process of society" (Hayek, 1973, p. 13). Therefore, the question is not determining what mathematical formulation better represents Hayek's notion of "large number of variables" (for example, combinatorial explosion, or other more or less refined tools). Rather, this notion highlights two limitations: informational and computational. The former implies that we cannot know *all* the facts. The latter emphasises that the human mind is able to control and manipulate only a few variables, and owing to this boundedness some complex problems are intractable (see section 3).

In addition, it should be pointed out that biologists and physicists are familiar with the idea of *levels of analysis* (Grobstein, 1973; Maturana and Varela, 1980, p. xxii; Auyang, 1998): classical mechanics is unsuitable for dealing with very small systems like atoms, and for this task it is replaced by quantum mechanics. This perspective leads to a traditional argument of theories of complexity, namely the emergence of collective behaviours which cannot be understood merely by referring to the properties of individual elements in complex systems.[19] Hence a given set of related components is definable as a "level of order" "because it has unitary properties at that level" which stem from the particular relationships among them (Grobstein, 1973, p. 32; see Ruelle,

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organization and interaction" and "Units at any given levels" "typically serve as 'building blocks' for constructing units at the next higher level".

1991, ch. 15). Pattee, as a physicist interested in the origin of life, endorses the view of complexity with reference to hierarchical structures and delineates the notion of a "control hierarchy" by means of which "the upper level [of a collection of subunits] exerts a specific, dynamic constraint on the details of the motion at lower level [i.e., selected individual subunits]" (Pattee, 1973, p. 77). The forces of constraint are thus associated with a (new) "hierarchical level of *description*" (p. 85), and this implies a "selective neglect of detail in favor of only a very limited number of crucial conditions" (p. 90). Parisi (1992) shows that an intermediate point of view between reductionist and global perspectives is possible: the starting point is the behaviour of individual components, yet it must also be considered that macroscopic behaviour does not change if there are small changes in the laws regulating the behaviours of individual elements. Therefore to be stressed is a certain independence and diversity of macro-systems with respect to micro-phenomena,[20] and this, as for Pattee's theory, calls to mind the near independence of Simon's nearly decomposable structures.

3. Complexity, "dispersed knowledge", and bounded rationality

The problem of knowledge in Hayek's work is one of the most widely debated themes in the literature, and a correlated argument is Hayek's unclear distinction between knowledge and information. In general, knowledge implies the capacity to process information, to apply abstract schemes, to solve problems, and to discover opportunities, whilst information refers to measurable data which must be mastered and organized by implicit or explicit knowledge (i.e. tacit or theoretical knowledge) (Fiori, 1998; Khalil, 2002). Moreover, knowledge "cannot simply be subsumed within 'information' as conceptualized in the economics of information literature" (Böhm, 1994, p. 160; cf. Butos and McQuade, 2002, p. 124), since, among other things, it is

[19] New qualities, unknown at microscopic level, appear at the macroscopic one, like temperature and gas pressure. Similarly, it cannot be determined whether a few molecules of water constitute a liquid or a solid state. Cf. Markose (2005, p. 165).

"embodied in skills and habits […] which are rarely expressible in theoretical or technical terms" (Gray, 1984, p. 37; see Lavoie, 1986).

In light of these problems, this section and the next treat the notions of "dispersed" and "inarticulate" knowledge in order to show how numerical and logical-relational approaches involve the view of knowledge and information in Hayek's work.

"Dispersed knowledge" (or the "fragmentation of knowledge") constitutes a fundamental Hayekian concept in favour of the market system, in that the latter is a mechanism able to provide individuals with useful, "relevant", knowledge and enable them to discover such knowledge by means of the competition process (Hayek, 1973, p. 14, cf. Hayek, 1978 [1968b], p. 179; cf. Kirzner, 1992 [1984], p. 154). Yet, the notion of "dispersed knowledge" defines knowledge in *quantitative and/or explicit* terms as a set of data or information about "particular facts": people do not know "*all the data* which enter into the social order", and each person possesses only a "small fraction" of the whole of information present in society (Hayek, 1973, p. 15; emphasis added). Therefore, this notion could be more precisely classified as *dispersed information* because it refers, in general, to measurable data and/or observable events. For example, measurable data concern (local) information about the (changeable) need for production factors, goods and services (Hayek, 1945, p. 83), while an observable event can be an item of (local) information which has an explicit form for someone (although, *stricto sensu*, not necessarily measurable), such as "To know of and put to use a machine not fully employed, or somebody's skill which could be better utilized" (Hayek, 1945, p. 80). In this sense, information of this kind is quantitative and/or explicit. In conclusion, "knowledge of the particular circumstances of time and place" consists in "unique information" possessed by each individual (Hayek, 1945, p. 80), and the difficulty of measuring and observing these circumstances depends on its spatial dispersion, and on the "continuous flow" characterizing the number of elements that agents must consider.

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[20] This hypothesis has been suggested by professor XXX, whom I thank, in a personal communication.

"Dispersed knowledge" is clearly linked to the concept of the large number of variables as the basic characteristic of complex phenomena. The crucial point is that these data (which take the form of local information) are not present all together to the actor, because they are dispersed in space and change at any point of time (Hayek, 1945, pp. 81-83). This framework involves a peculiar concept of bounded rationality because the notion of the "unavoidable imperfection of man's knowledge" (Hayek, 1945, p. 91) joins two separate concepts. The first is an informational limit of individuals, who are unable to know all the knowledge (information) dispersed in society. This limitation depends on the structures of the social environment. The second concept is the internal limitedness of the mind in processing a large amount of information (in general, *all* the information involved in complex phenomena). The former indicates that each agent possesses only limited information; the latter refers to individuals' cognitive and computational bounds.

This distinction appears in Simon's thought, although its characteristics are different with respect to Hayek's. On Simon's view, informational bounds are scarcely specified and involve the general relation between agents and the environment. By contrast, in Hayek's view on the informational limit is specified, in the sense that it appears when individuals do not possess certain information because of its spatial fragmentation. This perspective can be generalized if one considers that a similar lack of information also connotes social scientists and biologists, who cannot know all the elements (and their correlated properties) which constitute the object of their analysis, and this induces them to adopt the "explanation of the principle" (Hayek, 1979 [1942-1944], p. 73).[21]

Whilst on Simon's view computational limits occur when *too much information available at the same time* cannot be fully processed by agents (who consequently adopt heuristic procedures for handling problems),[22] for Hayek they essentially appear in one *extreme case*, that is, when an agent (usually a planner) is unable to deal with *all*

[21] Moreover, the flux of time causes a further loss of information about a number of events involved in evolutionary processes in both biology and social sciences.

[22] See Simon (1997 [1947], pp. 124 and 226). According to Simon, on the one hand, available information can be excessive, and he raises the problem of its cognitive processing. On the other, information is searched for by individuals when, in their problem-solving activities, they seek to achieve their goals through heuristic procedures.

the data (and not some of them) of an economic system. In this case, individuals' (planners') problems are "undecidable", not because no answer can be provided in a finite time (Foley, 1998, p. 46), but because, as matter of fact, nobody can collect all the information dispersed in society.[23] On the other hand, in the market environment, the market itself resolves computational problems of individuals because it enables them to obtain the proper amount of "relevant" and tractable information by means of discovery procedures.

In short, Hayek stresses the informational limits of the mind (rationality), which depend on the real structure of the social environment, while *internal* cognitive bounds (computational limits) have a less clear function in that they either appear prevalently in one *extreme* (unreal) *case* or can be resolved with help of market processes. As a consequence, Hayek seemingly does not analyze *intermediate cases*, i.e. individuals unable to process too much information – not all information – available to them at the same time, whilst he shows how *new*, relevant, knowledge can be obtained by means of discovery procedures. In fact, when the real environment is not complex (see section 2), information can easily be manipulated and organized for specific ends; otherwise it is better to leave the diffusion of information to the market mechanism.

In conclusion, on linking the "theory of complex phenomena" and the concept of "dispersed knowledge" it emerges that:

1) a large number of correlated variables is a condition for defining complexity;
2) these variables (which are specific "facts" in the real world and assume the form of information for individuals) exhibit spatial dispersion, and they change very rapidly over time. Hence, the corresponding information is a *flux*, rather than a set of fixed data (Hayek, 1945, pp. 81-83);
3) dispersed information affects the scientific explanation of social and evolutionary, biological, events, because we can produce only "explanations

[23] As regards the subject studied by social scientists, Hayek maintains that the "number of separate variables" (i.e. the whole number of events) which determine a change is "too large" and consequently cannot be mastered and processed (Hayek, (1979 [1942-1944], p. 73). More in general, social scientists and biologists can never know all the particulars of evolutionary processes. See section 5.

of the principle", given the impossibility of knowing the "very large number of particular facts" (Hayek, 1973, p. 23; cf. 1979 [1942-1944], pp. 73-74).

However, there is a further condition specifying the market as a complex phenomenon: its structure depends on informational relations among agents (the connections among individual parts qualify a complex order, organize it, and define its emergent properties). Therefore, both the abstract approach to complex phenomena, and the treatment of knowledge in the market, mix two different categories: the spatial dispersion of a huge amount of information does not *per se* explain the self-organizing and self-reproducing properties of a system, whereas the latter can be explained if we consider the distinctive connections among the system's components. This finding is confirmed by analysis of the notion of cultural evolution and of "inarticulate knowledge".

4. Complexity, evolution, and "inarticulate knowledge"

The theory of cultural selection is a fundamental component of Hayek's approach to complexity, in that evolutionary systems (like the market) are complex systems. The argument that Hayek puts forward is that certain rules and practices spontaneously emerged, and were unintentionally selected over others, because they gave (reproductive) advantages to the group which adopted them (Hayek, 1973, p. 17).

In *Notes on the Evolution of Systems of Rules of Conduct* (1967), Hayek maintains that "*selection* of rules will operate on the basis of the greater or lesser efficiency of the *resulting order of the group*" (Hayek, 1967a, p. 67, cf. Hayek, 1973, p. 17). The "important point" is that the general character of the "resulting order" is "the regularity of the conduct of the elements" (Hayek, 1973, p. 40). As a consequence, the order of actions is a basic emergent property which also appears in the formation of "correct expectations" (Hayek, 1973, p. 36), where evidently incorrect expectations would impede agents' coordination. All this is coherent with the concept of the "phenomena of organized complexity", where these latter crucially depend on the distinctive manner

in which the interactions among individuals are fulfilled (Hayek, 1978 [1975], pp. 26-27), since selected rules determine, in general terms, how individuals give shape to their reciprocal relations, and consequently to the social and economic order. Yet this argument is *logically* distinct from the one which relates complexity to the large number of variables, and once again it suggests that complexity can emerge from certain connections among variables, the number of which depends on the unit of analysis adopted.[24]

However, in Hayek's intention, the evolution of rules does not contradict his individualistic approach, specifically in economic theory, because the system of rules as a "whole" must be "interpreted as nothing else but an endeavour to reconstruct from regularities of the individual actions the character of the resulting order" (Hayek, 1967a, p. 72).[25] However, abstract rules enter into individuals' lives in terms of tacit, non-verbalized, knowledge to which agents refer in their behaviours and decision-making processes. In this sense, the case of the knowledge embodied in general, abstract, "rules of conduct" ("inarticulate knowledge") is very different from that of "dispersed knowledge".

Inarticulate knowledge is not measurable because it does not concern a large amount of "particular facts" dispersed in space. Rather, it defines *tacit*, cognitive, processes which refer to "schemata of thought which guide us" (Hayek, 1973, p. 31). It "can be described in terms of [unconscious] rules" which "govern the actions of the individuals […] without being known to the acting person in articulated ('verbalized' or explicit) form" (Hayek, 1973, pp. 18-19), and these characteristics render it neither measurable nor communicable.

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[24] "Very complex orders" comprise "more particular facts than any brain could ascertain or manipulate", yet they are explained referring to those "forces inducing the formation of spontaneous order" (Hayek, 1973, p. 38).

[25] The relation between individuals and order is described in terms of "integration" and interaction between "two different levels", individual and social, since individuals are themselves "complex systems" (the brain and society are "polycentric", spontaneous, orders (Hayek, 1967a, pp. 73 and 76; 1976, p. 15)). Therefore, agents are integrated in (and are influenced by) a larger complex system to whose creation they have contributed (Hayek, 1967a, pp. 76-77; see Lange-von Kulessa, 1997, p. 278). Yet this conclusion is problematic if one considers the well-known controversy on the potential contradiction between Hayek's notions of subjectivism and cultural selection. On this debate, and for references, see Hodgson (1993) and Caldwell (2000).

The two kinds of knowledge therefore imply different concepts. Dispersed knowledge (information) refers to well-defined circumstances or facts; it is individual in nature and may be non-shared with others. "Inarticulate knowledge" implies a cognitive process which unconsciously guides behaviours, is shared by people in that it is embodied in general "rules of conduct", helps coordination among individuals' plans and actions, and allows the exploitation of environmental (market) knowledge, the discovery of opportunities, and the creation of a shared framework in which subjects interact. Moreover, it is not "factual knowledge" (information), but rather an abstract capacity of the mind which operates by means of rules of a special kind. Hayek tends to mix the two notions, because the cultural selection of rules explains the emergence of the spontaneous market order, and inarticulate knowledge, incorporated in abstract rules, enables an individual to discover the dispersed information possessed by others. Finally, inarticulate (tacit) knowledge produces individual skills and is therefore as fragmented as dispersed knowledge. Nonetheless this fragmentation does not explain its properties.

The theoretical distinction between the two forms of knowledge is important because it provides new elements with which to interpret complexity. In fact, inarticulate knowledge is closely related to spontaneous orders, in that it is a by-product of the set of evolving rules that has unintentionally taken shape over time. This framework shows the application of the general theory of complexity to the market, since these rules connote the market and the social order (i.e. complex phenomena) in terms of specific relations among individuals (i.e. connections among separate parts) (Hayek, 1973, p. 36). Yet, this perspective does not necessarily imply that spontaneous orders arise in relation to large number of variables. As Hayek himself maintains "Spontaneous orders are not necessarily complex" (Hayek, 1973, p. 38), as shown, for example, by the systems of rules regulating primitive, small, groups (as simple phenomena) and which have emerged spontaneously, and unintentionally, via the same processes which connote the emergence of rules in the complex "Great Society" order. Yet, when Hayek deals with "very complex orders", he views the two conditions (number of variables and connections among components) as co-essential in any

circumstance (Hayek, 1973, pp. 36 and 38). Thus "dispersed knowledge" is treated jointly with "inarticulate knowledge", and it seems to reflect the (logically separable) part of Hayek's theory of complex phenomena which refers to "large number of variables" as a basic explanatory concept.

5. The "Explanations of the principle" and the "Compositive method"

The criterion of the "large number of variables" is evoked, as we have seen, in order to introduce the notion of the "explanations of the principle". This latter is correlated in *Scientism* to the "compositive method" (see section 1) which, according to Hayek, must be used in the social sciences, in that "concepts and views" of individuals "form the elements from which we build up, as it were, the more complex phenomena" (Hayek, 1979 [1942-1944], p. 65). Explanation of the principle (here "knowledge of the principle") arises in the place of knowledge about all the details of complex phenomena because the social scientist

> "*will scarcely ever know even all of the elements* of which [his field of research] consists and he will certainly never know *all the relevant properties of each of them* […] The number of separate variables which in any particular social phenomenon will determine the result of a given change will as a rule be far too large for any human mind *to master and manipulate* them effectively." (Hayek, 1979 [1942-1944], p. 73; emphasis added).

The first sentence stresses the insurmountable lack of information: social scientists never know *all* the elements (and related properties) which they study. The second one points out their cognitive and computational limits: the human mind cannot master too large a number of variables (see section 3). Hence, the "explanation of principles" arises from the connection of two distinct problems. Yet the "explanation of the principle", *in this form*, points up an informational, quantitative, problem which persists in Hayek's mature work. The premise is that, as regards "very complex phenomena", the powers of science are "limited by the practical impossibility of

ascertaining all the particular facts"; therefore "science consists not of the knowledge of particular facts" (Hayek, 1973, p. 15). The problem delineated is a lack of information, which is shared by diverse disciplines, from social sciences to biology. Thus, on discussing of the theory of evolution in order to show its applicability to social and market spontaneous orders, Hayek maintains:

> "The theory of evolution proper provides no more than an account of a process the outcome of which will depend on a very large number of particular facts, *far too numerous for us to know in their entirety*, and therefore does not lead to predictions about the future. We are in consequence *confined* to 'explanations of the principle' or to predictions merely of the abstract pattern the process will follow." (Hayek, 1973, pp. 23-24; emphasis added)

Therefore, the informational limit (the huge and unobservable number of facts) connotes the explanations of the principle, and the need to overcome requires analysis of "particular facts" to be replaced with that of "types of elements". However, on reasoning counterfactually, one may pose the following question: if all the specific facts involved in complex social and biological phenomena were known by scientists, would the resulting explanation (or reconstruction by means of details) be just as good as the "explanation of the principle"? Hayek's answer is "yes". More precisely, it would be better because it allows exact predictions to be made, whereas "explanation of the principle" is a second-best solution[26] and cannot be falsified (Hayek, 1967 [1964] p. 29). In other words, if a complete description were possible, complexity would disappear, because its fundamental feature – the presence of a large number of *unknown* facts – would also disappear. Therefore, "explanation of the principle" (described in these terms) appears to be more a limited device, derived from a lack of observational and computational capacities, than an *alternative instrument* able to

[26] "Of course, compared with the precise predictions we have learnt to expect in the physical sciences, this sort of mere pattern predictions is a *second best* with which one does not like to have to be content." (Hayek, 1978 [1975], p. 33; emphasis added). Therefore, Ebenstein (2003, p. 173) maintains "Hayek embraced prediction as the criterion for scientific theories".

provide a better explanation of complex phenomena[27] on the basis of a logical dimension different from the analysis of details.[28]

In my view, this is a consequence of that part of Hayek's theory which defines complexity in informational (and quantitative) terms. This approach does not envisage the reconstruction of complex events by collecting particular facts (on the basis of a specific theory) or reconstructions by means of "principles" as explanations alternative in their nature. It does not connect the different *levels of analysis* of both types of *reconstructions* to different operational and explanatory dimensions.[29] On the other hand, when, in *The Theory of Complex Phenomena*, Hayek defined the movement from "inanimate" to "animate" worlds as a matter of degree, measurable in terms of the increasing number of variables included in a model, he evoked the same logical perspective – that of continuity between those universes – instead of showing both their discontinuity and the discontinuity of the theoretical approaches required to explain inorganic and living worlds. From this point of view, the approach based on levels of analysis focuses on a perspective different from the one based on continuity among low and high degrees of complexity, where large-scale problems seem to be amplified versions of small-scale ones.

Yet there is another side to Hayek's thought which describes complexity in terms of connections among individual parts by means of which organized structures and emergent properties appear as wholes. This view focuses on the changeable network of relations from which the properties of systems (spontaneous orders) emerge. It does not

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[27] Hayek himself points out that analysis of the principles and of details are not alternative tools. In fact, "[I]t should perhaps be stressed that there can *never be competition* between the two procedures, because what we have called an explanation of the principle will always give us only part of the *information* which a full explanation would yield where it can be achieved, and because in this sense the former is a *less powerful instrument*." (Hayek, 1967 [1955], p. 21; emphasis added).

[28] It should be borne in mind that, for Hayek, "facts" are only the events that sciences classify as such, and this is coherent with both his endorsement of Popper's criticism of inductive generalizations (Hayek, 1967 [1955], p. 4), and his view of "The place of theory in historical knowledge […] in forming or constructing the whole to which history refers" (Hayek, 1979 [1942-1944], p. 125). Therefore, evaluation of details is included in the theory which considers an analytical reconstruction of facts to be a substitute for the one based on "types of elements".

[29] Hence, "reductionism" is not rejected as an ill-suited level of analysis, but rather because of the impossibility of providing "an exhaustive enumeration of all the physical circumstances" in biological and mental phenomena (Hayek, 1967 [1964] p. 39). As consequence, one infers, when such a description is achievable, application of the reductionist approach is possible.

examine large amounts of variables (to which correspond large numbers of particular events), but instead seeks to delineate a different mechanism, i.e. a logical approach not reducible to a more detailed description of phenomena (Hayek, 1973, p. 39). "Explanation of the principle", if conceived in this terms rather than as a by-product of the informational and computational limits of scientists, incorporates this perspective, although it is subsumed in the informational (quantitative) one.

Finally, the relation between the "compositive method" and the "explanations of the principle" highlights a peculiarity in Hayek's theory. The former is a specific method for a specific discipline connoted by some sort of uniqueness with respect to other scientific domains because of the nature of its subject. By contrast, the latter includes the subject studied by social sciences from a different methodological perspective which associates it with other disciplines exhibiting some shared general features.

The uniqueness of the social sciences with respect to the natural sciences is due to the fact that ideas, beliefs, and opinions – called "constitutive of phenomena" – "become the causes of a social phenomenon". Therefore, the social scientist "starts from the concepts which guide individuals in their actions", and this permits him/her to reconstruct social complex phenomena as "wholes", and to describe them as the unintentional results of human action (Hayek, 1973, p. 20). This is – Hayek says – the "characteristic feature" of the methodological individualism with which the subjectivism of the social sciences is closely connected (Hayek, 1979 [1942-1944], pp. 62-64).

When the argument concerns the complexity determined by a huge number of particular facts, the differences among the social sciences, evolutionary biology, and other disciplines (system theory, cybernetics, etc.) are not considered. And "explanation of the principle" becomes a suitable approach for dealing with these domains. Since Hayek considers the Darwinian theory of evolution to be the best example of the explanation of the principle (Hayek, 1967 [1955], p. 11-12; 1967 [1964], p. 31; 1973, p. 16), I shall essentially refer to this theory in the following remarks.

The fundamental point is that the "wholes" (the "orders") treated by the social sciences and evolutionary biology are fundamentally different, in that the former are constructions of human action, which depend on "beliefs and opinions". The latter are generated by impersonal forces, whose elements do not possess intentionality, concepts, beliefs, and opinions; and this objective world exists independently from human action (cf. Fleetwood, 1995).[30] In the perspective of the "explanation of the principle", social orders lose part of their specificity. They are dealt with in the same ways as impersonal, biological, "wholes", because they share with these latter an analogous, objective and huge number of elements, whose connections spontaneously produce a certain order. If we assume this point of view, we cannot refer to methodological individualism, subjectivism, and compositive method, since they cannot treat "wholes" such as those studied by biology. In short, the focus is on a methodological point: on the one hand, subjectivism has a precisely-defined domain not reducible to others; on the other, "explanation of the principle" provides a different perspective showing that social phenomena can be compared to other realms (in particular, biology). Yet this requires observation of these domains in objective terms:[31] that is, considering them on the basis of their huge number of elements, independently from their specificity.

Conclusions

The theory of complexity was an important part of Hayek's work. It was treated in his writings from the 1940s onwards, where he emphasised the role of a large amount of variables and their interactions in distinguishing complex from simple phenomena, and it was subsequently harmonized with his evolutionary approach. This framework enabled Hayek to propound a powerful theory of the market and, in general, of spontaneous orders. Yet the two terms, which define complex phenomena, exhibit a

[30] Of course, humans can modify nature, yet evolutionary forces are not created by man.

different logical dimension: the one is, so to speak, quantitative, whilst the other is explanatory. The one construes complexity by referring to the huge amount of data which a model must consider in terms of variables; in this sense, the world is more *complicated* than *complex*. The other dimension deals with complexity by using an explanatory category, connoted in logical-relational terms, where the system's emergent and self-organizing properties depend on interactions among its components. Nonetheless, this framework reminds us that, for Hayek, *both models of simple and complex phenomena are characterized by connections among variables*, and their difference is essentially due to the number of variables which they contain. Therefore, the *numerical* criterion predominates.

Moreover, Hayek conceives the move from inanimate (simple phenomena) to the animate and social world (complex phenomena) in terms of continuity, as a mere increase in the number of variables considered by a model representing them. On the contrary, comprehension of this move requires a different epistemological category able to explain the emergence of the living and social world. Hayek's theory comprises this analytic term in outline form (the logical-relational one, although, I repeat, connections among elements characterize simple phenomena as well). Yet he distinguishes neither between *numerical* and *logical-relational* concepts nor between the relative levels of analysis. The same problem arises when, on discussing "organized" and "unorganized" complexity, Hayek mixes the explanatory concept of (complex) "organization" with the "large number of particulars", where the latter (contrary to the former) does not say much about the properties of an organized structure, and does not explain why some complex phenomena are organized and others are not.

The dualistic view permeates Hayek's work, and it also appears when problems of bounded rationality are addressed. In particular, the large (*infinite*) number of "facts" (the empirical variant of the large number of variables in a model) connotes Hayek's notion of bounded rationality, where limits to computation emerge not with respect to

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[31] As previously pointed out, for Hayek objectivity is the result of a reconstruction which depends on how a theory selects facts.

excessive information (however tractable this may be by means of heuristic procedures) but with respect to *all* the information of an economic system. Hence, rationality cannot overcome the informational gap of fragmented knowledge, while individual, computational, limits can be resolved by resorting to the market.

The *numerical* view also connotes Hayek's concept of knowledge, specifically "dispersed knowledge". This consists in fragmented (individual) information, that is, a set of measurable data (or observed events) possessed by individuals in terms of "unique information" about "particular facts". Hence dispersed knowledge is a quantitative/informational concept. Yet this kind of "knowledge", considering all individuals, is *infinite*, and nobody can collect it owing to its spatial dispersion. Closely connected, but analytically different, is the notion of "inarticulate knowledge", which implies tacit cognitive processes characterized by unconscious abstract rules used by agents to interpret reality and adopt suitable behaviours. These general rules are the result of cultural selection, and they are shared by the members of society. Yet they involve an epistemological perspective different from that of "dispersed knowledge" because they do not require the numerical dimension. Although inarticulate (tacit) knowledge is as fragmented as dispersed knowledge, because it belongs to individuals, its peculiarity is that it generates skills, unconscious capacities, and tacit rules of behaviour, where rules, like the mind, are abstract mechanisms which determine the "primacy of the abstract" in society.

Finally, this dualistic approach is reproduced in the "explanations of the principle" which are adopted because "particular facts" studied by social and biological sciences are too numerous to be analyzed in detail. Yet, they somehow capture the evolutionary process and provide a description of its structure. Therefore, once again, two different theoretical dimensions cohabit, although one (here called "numerical") generally prevails over the other.

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