# Prediction in Economics and Complexity: The Role of Parsimonious Factors[1]

Wenceslao J. Gonzalez

(University of A Coruña, Spain).



## 1. Many Faces of Complexity in Economics and Prediction

Complexity is a key feature in the sciences of design from the point of view of their framework —or constitutive elements— as well as of their dynamics. This twofold complexity affects economics insofar as it is one of the sciences of the artificial.[2] In this regard, economics is a "science of design" that enlarges our possibilities towards the future and uses prediction as a basis for decision-making.[3] But economics is also a social science that deals with human needs. This feature adds more factors to the

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[2] Cf. SIMON, H. A., *The Sciences of the Artificial*, 3rd ed., The MIT Press, Cambridge, MA, 1996 (1st ed., 1969; 2nd 1981).

[3] Cf. HOLT, C. C., "Rational Forecasting, Learning, and Decision Making," in AUGIER, M. and MARCH, J. G. (eds.), *Models of a Man: Essays in Memory of Herbert A. Simon*, The MIT Press, Cambridge, MA, 2004, pp. 355-363.

analysis of its complex configuration as a science and its dynamic evolution. Commonly, the studies on complexity in economics are focused on particular forms of expression of complexity rather than on the roots of this problem as a dual science (i.e., artificial and social).[4]

Within the framework of the structural and dynamical complexity of economics, there is complexity related to economic predictions. Moreover, complexity is one of the reasons, which is frequently used for arguing that prediction in economics is more difficult than prediction of natural events (including the weather forecast or even the prediction of climate change). This complexity is important because prediction is a crucial methodological issue in economics which has been used as a "scientific test" by influential economists;[5] and prediction is the support used for making prescriptions in order to resolve practical problems (e.g., in national economy or in international trade).

### 1.1. Sources of Complexity for Economic Predictions

Undoubtedly, economic predictions are related to social needs (e.g., supply and demand of food, housing, clothing, etc.) as well as to artificial enlargements of human society by means of new designs, both at the micro and at the macro levels. The nexus between both levels —micro and macro—

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[4] See the three volumes on this issue: BARKLEY ROSSER JR. J. (ed.), *Complexity in Economics*, E. Elgar, Cheltenham, 2004. Volume 1, entitled *Methodology, Interacting Agents and Microeconomic Models*, has a short part I on "Philosophical and Methodological Overviews", only a fifth of the whole extension of the volume. It is followed by part II on "Social Interactions and Learning Dynamics", part III on "Competitive Market Dynamics", and part IV on "Dynamics of Imperfect Competition". Volume II, entitled *Macroeconomics, Financial Markets and International Economics*, is divided in three parts: I) "Macroeconomic Fluctuations and Growth"; II) "Financial Markets", and III) "International and Transitional Economic Dynamics". Volume II, entitled *Urban-Economic Models, Evolutionary Economics and Ecologic-Economic Systems*, is also divided in three parts: I) "Urban and Regional Systems"; II) "Evolutionary Economic Dynamics"; and III) "Ecologic-Economic Systems."

[5] On this issue, the perspectives of four Nobel laureates in economics (Milton Friedman, John Hicks, James Buchanan and Herbert Simon) are analyzed in GONZALEZ, W. J., "Prediction as Scientific Test of Economics," in GONZALEZ, W. J. and ALCOLEA, J. (eds), *Contemporary Perspectives in Philosophy and Methodology of Science*, Netbiblo, A Coruña, 2006, pp. 83-112.

are far from simple. In the case of prediction, these differences in the kind of phenomena predicted should be taken into account, especially in epistemological and methodological terms.

Another duality is ontological: "economic activity" and "economics as activity." This distinction offers a central source for complexity in economics as a human undertaking. On the one hand, economic activity has specific characteristics as such; and, on the other hand, economics is a human activity that is related to other human activities (social, political, cultural, ecological, etc.)[6], which makes prediction interwoven with several kinds of complexities.

Furthermore, economics is a human activity that is developed by individual agents who are related to organizations and markets. Those individuals display *creativity* when they perform some actions, and this creativity adds another element to the complexity in making economic predictions. Thus, there are at least several components of complexity involved here that may have consequences for making economic predictions.

Starting from a social ontology, these sources of complexity resemble a scale with several steps: a) the social and artificial realms; b) the micro and macro levels; c) the degree of autonomy as human undertaking ("economic activity" and "economics as activity"); d) the organizations and markets; e) the role of individual agents (i.e. creativity in different realms); ...

All of them are at stake in front of a classical question: why are economic predictions so difficult? This central question, crucial for explaining their frequent unreliability, has a direct answer: the many faces of complexity of economic reality. In other words, there is an enormous

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[6] This distinction between "economic activity" and "economics as activity" is developed in GONZALEZ, W. J., "Economic Prediction and Human Activity. An Analysis of Prediction in Economics from Action Theory," *Epistemologia*, v. 17, (1994), pp. 253-294; specially, pp. 261-280.

variety of "respects" that could make a difference among economic events, and there exist complex ways in which the economic influences operate and interact with each other.

For Amartya Sen, "one source of this complexity lies in the difficulty in anticipating human behaviour, which can be influenced by a tremendously varied collection of social, political, psychological, biological and other factors. Another source is the inherent difficulty in anticipating the results of interactions of millions of human beings with different values, objectives, motivations, expectations, endowments, rights, means and circumstances, dealing with each other in a wide variety of institutional settings."[7]

Parsimonious factors can have a role here dealing with the problem of complexity in economics, which is a main source of difficulty for economic predictions. Parsimonious factors do not look for "simplicity" (a single ingredient or a central axis); they seek sobriety in the selection of elements in order to offer those that are central for the complex system. This austere selection of factors should be able to present the set of elements that is sufficient and necessary to grasp the complex system.

This study of the parsimonious factors in economics, thinking of important aspects for predictions, can be focused towards it as a science of design. This inquiry requires taking into account some features, among them: a) the twofold complexity of economics as a science of design —its framework and dynamics—, and b) the possibility of being facing a sort of complexity open to a hierarchical articulation (i.e., an organized complexity internally articulated).

Accordingly, the identification of parsimonious factors in economics, understood as a large complex system, should lead to the clarification of its scientific framework and its evolving dynamics. This identification should

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[7] SEN, A., "Prediction and Economic Theory," in MASON, J., MATHIAS, P. and WESTCOTT, J. H. (eds.), *Predictability in Science and Society*, The Royal Society and The British Academy, London, 1986, p. 5.

search a possible hierarchical articulation in the architecture of the particular complex system. Thereafter, the parsimonious factors can contribute to build upon it in order to overcome the complexity of economics predictions. The contribution might be mainly in the task of increasing the accuracy and precision of the predictive models created in economics.

### 1.2. General Obstacles to Predictors

Underneath the analysis of complexity in economics, understood as an influential factor of difficulties for economic predictions, there is the problem of the obstacles for making scientific predictions in economics. On the one hand, prediction is not a simple concept, especially from a *methodological point of view*, because in economics its use is twofold: prediction is a test for evaluating theories, and it is also a guide used for policy. Thus, prediction needs to address a diversity of problems related to the knowledge of the future, both as basic science and as applied science. And, on the other hand, those problems lead to *obstacles* to scientific prediction. *De facto*, there are diverse kinds of limits on scientific prediction in social and artificial realms, such as economics.

Certainly, prediction is not a simple concept insofar as it deals from the outset with a variety of methodological problems, mainly in the social sciences: "The nature and complexity of what one extrapolates from, the precision with which the processes of development are thought to be known, whether the outcome predicted has a contaminating effect on the prediction in question and may thus modify it, how far into the future this extrapolation is intended to predict, the range of variables which can be accommodated in calculations: all these are some of the many and more obvious problems which make foretelling the future a hazardous business."[8]

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[8] HOWE, L., "Predicting the Future," in HOWE, L. and WAIN, A. (eds), *Predicting the Future*, Cambridge University Press, Cambridge, 1993, p. 4.

Following the methodological difficulties for prediction in economics, we can reach the epistemological problems and the ontological basis. In this regard, there are limits on scientific predictions in economics. They could be on "internal" aspects related to scientific activity or on "external" features of human capacities or social capabilities. The former belongs to the sphere of the *constituents of science* and the limits pointed out by them (semantic, logical, epistemological, methodological, ontological, axiological and ethical), whereas the latter are in *human agents* and their institutions.

Consequently, within the framework of a social and artificial science, economic models need to deal with the nature of things where choice or chance —and even chaos— can have a role, which can lead to creativity in human undertakings (e.g., creation of artificial products as "hedge funds"). On the ontological level, Herbert Simon has pointed out that we "don't know whether the economy is a chaotic system."[9] Meanwhile, at the epistemological level, our cognitive limitations are undeniable, as the bounded rationality approach has repeatedly emphasized.

From a general point of view —focusing mainly on ontological and epistemological aspects—, Nicholas Rescher calls attention to the *principal impediments* to predictability. 1) Anarchy, where there is lawlessness in the strict sense of the absence of lawful regularities to be linking mechanisms. 2) Volatility, when there is an absence of nomic stability and then of cognitively manageable laws. 3) Uncertainty, which is the lack of information about the operative mechanisms.[10] 4) Haphazard, when the lawful linking mechanisms do not permit the secure inference of particular conclusions: a) *chance* and *chaos* (stochastic or random processes which make laws at issue irretrievably probabilistic); b) *arbitrary choice*

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[9] SIMON, H. A., "The State of Economic Science," in SICHEL, W. (ed), *The State of Economic Science. Views of Six Nobel Laureates*, W. E. Upjohn Institute for Employment Research, Kalamazoo, MI, 1989, p. 99.

[10] We can distinguish between the uncertainty that we are aware of ("what we know that we do not know") and the uncertainty that is actually beyond us ("we do not know that we do not know").

(determinations that are basically groundless and so rationally intractable), and c) change and innovation (a kind of novelty that make outcomes not foreseeable because prediscernible patterns are continually broken). 5) Fuzziness, which is data indetermination whether individually or in a collectively conjugate way. 6) Myopia, which is data ignorance in the sense of lack of sufficient volume and detail to be able to make a prediction. 7) Inferential incapacity, which is the infeasibility of carrying out the needed reasoning.[11]

Obviously, these impediments to predictability have a relation to complexity. Rescher recognizes that, for many writers, "complexity is determined by the extent to which chance, randomness, and lack of lawful regularity in general is absent."[12] But this inverse of simplicity is an issue of *degree*: the system can be more or less complex. In the case of economics, the tendency is to focus on some of the previous impediments to predictability, where uncertainty has a key role from the methodological point of view (mainly in applied economics).[13]

When economists point out central obstacles for an adequate or reliable prediction, there are some differences of emphasis according to the diverse economic schools. These issues are usually connected with central epistemological and methodological controversies: the possibility of economics laws, the way of understanding "causality" in economics, the role attributed to economic creativity of individual agents, etc. They are also connected to ontological aspects (the kind of novelty in the real world).

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[11] Cf. RESCHER, N., *Predicting the Future*, State University Press New York, New York, 1998, pp. 134-135.

[12] RESCHER, N., *Complexity*: *A Philosophical Overview*, Transaction Publishers, New Brunswick, NJ, 1998, p. 8.

[13] In the case of prediction, the methodological role of uncertainty is very important. Thus, once outcomes of economic forecasts are known, "the corresponding forecasts errors and the anticipated forecast uncertainty can be used to evaluate the models from which the forecasts were generated," ERICSSON, N. R., "Predictable Uncertainty in Economic Forecasting," in CLEMENTS, M. and HENDRY, D. F. (eds.), *A Companion to Economic Forecasting*, Blackwell, Oxford, 2002, p. 19.

But insofar as these economists are aware of doing science, the attitude of economists is commonly to emphasize some "stable" elements (epistemological and methodological): human rationality in the decision-making,[14] capacity of gathering and observing unobvious regularities,[15] etc. Therefore, economists try to overcome these obstacles of predictability and, at the same time, they are well aware of the present stage of economic predictions.[16]

What seems clear is that, ultimately, there are ontological roots: the difficulty of the methodological problem of prediction in economics —its necessity and unreliability— lies in the *complexity* of human activity inserted in the social setting.[17] This complexity contributes to the frequent unreliability of economic predictions, which have their roots in the subject matter of this science: economic reality is a social undertaking commonly mutable as a consequence of its dependence on human activity, historically developed.

Nevertheless, "economic activity" is an objective and measurable reality. In addition, economics as an *activity among others* is also objective but more difficult to measure. Most of the econometric models of neoclassical economics focus on "economic activity," something that can be

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[14] On this issue, GONZALEZ, W. J., "Racionalidad y Economía: De la racionalidad de la Economía como Ciencia a la racionalidad de los agentes económicos," in GONZALEZ, W. J. (ed), *Racionalidad, historicidad y predicción en Herbert A. Simon*, Netbiblo, A Coruña, 2003, pp. 65-96.

[15] Cf. HOOVER, K. D., "Econometrics and Reality," in MÄKI, U. (ed), *Fact and Fiction: Foundational Issues on Economics and the Economy*, Cambridge University Press, Cambridge, 2002, p. 173.

[16] Cf. CLEMENTS, M. P. and HENDRY, D., "Explaining Forecast Failure in Macroeconomics," in CLEMENTS, M. and HENDRY, D. F. (eds), *A Companion to Economic Forecasting*, Blackwell, Oxford, 2002, pp. 539-571. See also FRANSES, PH. H., "Forecasting in Marketing," in ELLIOT, G., GRANGER, C. W. J., and TIMMERMAN, A. (eds.), *Handbook of Economic Forecasting: Volume 1*, Elsevier, Amsterdam, 2006, pp. 983-1012.

[17] "The economy consists of the activities of many millions of decision makers, acting largely independently but sharing information used in forming their decisions: the economy is thus very complicated," GRANGER, C. W. J., "Evaluation of Forecasts," in HENDRY, D. F. and ERICSSON, N. R. (eds.), *Understanding Economic Forecasts*, The MIT Press, Cambridge, MA, 2001, p. 93.

considered in itself.[18] But the ongoing economic crisis reveals the need to pay attention to the complexity of economics as an activity interconnected to other activities (social, political, cultural, ecological, etc.).[19]

## 2. Varieties of Complexity: Framework and Dynamics

Initially, there is a *duality* in the kind of complexity present in the sciences of design, such as economics. Complexity might appear both in their constitutive components (when they are arranged as a complex framework) and in the dynamics (when the elements operate as a teleological procedure open to many possibilities in the future). (i) There is a complexity in their configuration as a *complex framework*. This can be seen in the constitutive elements of a science of the artificial (language, structure, knowledge, method, activity, aims, and values). (ii) There is a complexity in the *dynamics* of a science of design, especially as an applied science, because this teleological human activity involves aims, processes, and results. A science of design can seek the resolution of concrete problems using a complex system organized by aims, processes, and results.

### 2.1. Complex Framework and Complex Dynamics

According to this initial duality in the kind of complexity present in the sciences of design, economics as a science of the artificial might have both features: a complex framework of components to *explain* and *predict* phenomena as well as a complex dynamics that seeks the *resolution of specific problems* in the social milieu. In the case of the complex framework the main components are semantic, logical, epistemological, ontological, axiological and ethical. Meanwhile the complex dynamics of the sciences of

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[18] Cf. MORGAN, M. S., *The History of Econometric Ideas*, Cambridge University Press, Cambridge, 1990.

[19] Some economists, such as Joseph Stiglitz (Nobel Prize winner in 2001), are insisting on the need for new parameters for economics: the mere values of market activity are not good enough for measurement national economies, where the social and economic elements are deeply interwoven.

design requires a methodology that involves aims, processes and results. They evolve as a complex system in historical terms.

An approach to complexity as a *constitutive element* of the sciences of the artificial can be found in Herbert Simon. Firstly his focus is on "organized complexity," and secondly he seeks a complexity that might be characterized in ontological terms. Thus, he is not interested in a possible chaotic structure (e.g., in economics as a presumptive chaotic system) but rather in what he calls "an architecture of complexity."[20] This ontological complexity allows for a hierarchical configuration. Thus, a) the set is *eo ipso* decomposable —or rather "nearly decomposable"— following a hierarchical dimension (priorities), and b) the elements obtained —subsystems— may be coordinated, insofar as it is an organized complexity.

Above and beyond the constitutive elements of a science of design —only some of them are studied by Simon— there is another angle: the *dynamic domain* in the sciences of the artificial —aims, processes, and results—, which is evolving as a complex system. When the complex system —such as branches of economics— is evolving, the internal structure is open to the future in many ways: a) the evolution might be for an adaptation to the available environment;[21] b) the variation can be a historical modification of the system through the emergence of new properties;[22] c) the historical modification might be a structural change that ends up being

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[20] Cf. SIMON, H. A., "The Architecture of Complexity," *Proceedings of the American Philosophical Society*, v. 106, n. 6, (1962), pp. 467-482. Reprinted in EARL, P. E. (ed.), *The Legacy of Herbert Simon in Economic Analysis, Vol. 1*, E. Elgar, Cheltenham y Northampton, MA, 2001, pp. 485-500.

[21] "To predict the short-run behavior of an adaptive organism, or its behavior in a complex and rapidly changing environment, it is not enough to know its goals. We must know about its internal structure and particularly its mechanism of adaptation," in SIMON, H. A., "Theories of Decision-making in Economics and Behavioral Science", *American Economic Review*, v. 49, (1959), p. 255. Reprinted in SIMON, H. A., *Models of Bounded Rationality*. Vol. 2: *Behavioral Economics and Business Organization*, The MIT Press, Cambridge, MA, 1982, p. 289.

[22] Cf. SCHENK, K.-E., "Complexity of Economic Structures and Emergent Properties," *Journal of Evolutionary Economics*, v. 16, (2006), pp. 231-253.

a new complex system (such as the changes in the business firms related to information and communication technologies); etc.

Assuming a hierarchy of components within the complex system —an internal framework—, Simon analyzes the speed of evolution by means of the interaction of components (a complex dynamics).[23] For him, complex systems are nearly completely decomposable and, in the case of human systems, their search for coordination is explicit. This coordination in the sciences of the artificial can be carried on through bounded rationality — present both in science as human activity and in the agents— and using parsimonious factors to get the whole system analyzed.

On the one hand, the sciences of design are sciences of the artificial — due to a task of synthesis—, and their subsystems can be taken back to other more basic ones. Thereafter, starting from these basic ingredients, it is possible to do research on the system as a whole. And, on the other hand, the methodological conception of parsimony allow us to focus on the elements needed in the system, instead of searching the mere simplicity of a central axis or a single directive idea.

Ontologically, Simon understands complexity in the sciences of the artificial as endowed of an internal hierarchy, and epistemologically he assumes that configuration is always "nearly decomposable."[24] In addition, methodologically he develops some cases starting from a conception of parsimony.[25] But a deeper analysis of the complex framework —or constitutive elements— as well as the dynamic domain of the sciences of design (aims, processes, and results) should be made. This analysis requires

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[23] Cf. SIMON, H. A., "Near Decomposability and the Speed of Evolution," *Industrial and Corporate Change*, v. 11, n. 3, (2002), pp. 587-599.

[24] Simon had important contributions to the sciences of the artificial. He was both Nobel Prize in Economics (1978) and a key figure in *Computer Sciences* who received the Alan Turing Award with Allen Newell (1975).

[25] Cf. SIMON, H. A., "Science Seeks Parsimony, not Simplicity: Searching for Pattern in Phenomena," in ZELLNER, A., KEUZENKAMP, H. A. and MCALEER, M. (eds.), *Simplicity, Inference and Modelling. Keeping it Sophisticatedly Simple*, Cambridge University Press, Cambridge, 2001, pp. 32-72.

a wide conceptual framework. In this regard, Nicholas Rescher offers a broader perspective in his book *Complexity*.[26] He emphasizes that a complex system can be organized into subsystems not only in hierarchical terms but also coordinately, through the network of its relations.

In order to develop a deeper analysis of the complex framework as well as the dynamic domain of the sciences of design, a central feature to be considered is this: they are applied sciences.[27] In addition, they assume bounded rationality in three successive levels: i) in science, insofar as it is a human-made undertaking; ii) in the diverse sciences, when they develop an specific modality of rationality according to the kind of problem that they deal with (such as issues in the fields of economics, information science, communication, etc); and iii) in the agents, when they work on the decision-making of agents in the realms analyzed (economic, documentary, communicative, etc.).

Through the epistemological notion of "bounded rationality" and the use of a methodology of parsimonious factors it should be possible to research the problem of complexity. This might be made in two directions: to achieve the key elements within an internal *hierarchical articulation* in the system analyzed (economic, documentary, communicative, etc.) and to grasp the reciprocal relations of elements —the interconnection— that allow us finding a *coordination* within the system.

### 2.2. Relevant Forms of Complexity

*Prima facie*, it could be puzzling to read "there is still no generally accepted definition of complexity, despite a vast number of proposed *ansatzes*."[28] Moreover, Simon himself, when dealing with the architecture of

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[26] See RESCHER, N., *Complexity: A Philosophical Overview*, pp. 8-16.

[27] Cf. NIINILUOTO, I., "The Aim and Structure of Applied Research", *Erkenntnis*, v. 38, (1993), pp. 1-21; and NIINILUOTO, I., "Approximation in Applied Science," *Poznan Studies in the Philosophy of Sciences and the Humanities*, v. 42, (1995), pp. 127-139.

[28] CHU, D., STRAND, R. and FJELLAND, R., "Theories of Complexity. Common Denominators of Complex Systems," *Complexity*, v. 8, n. 3, (2003), p. 19. "There is no agreed-upon

complexity, avoids a formal definition of "complex systems", those that may be either disorganized or organized. By *complex system* he means "one made up of a large number of parts that have many interactions."[29] In addition, he points out that the whole is more than the sum of the parts in such systems, and it is not a trivial matter to infer the properties of the whole, given the properties of the parts and the laws of their interaction.

However, these characteristics given by Simon of a "complex system" are not good enough, because few realities of our world (natural, social and artificial) seem exempt from these relations between the parts and the whole through rules of interaction.[30] Another way of tackling this issue is by paying attention to "modes of complexity", trying to grasp what they share as common features. An interesting collection of modes of complexity can be found in Rescher's analysis. He distinguishes three large modes of complexity: a) epistemic (complexity related to formulas); b) ontological, which are those connected to composition and structure; and c) functional.[31]

Epistemic modes of complexity for Rescher are threefold: i) descriptive; ii) generative; and iii) computational. Within the ontological modes of complexity, there are two blocks: on the one hand, compositional complexity (constitutional and taxonomic or heterogeneity); and, on the other hand, structural complexity (that associated with the ways of organization and to the hierarchical configuration). In the case of functional complexity, there are —for him— two options: operational and nomic.

All these features together lead to a concept of "complexity" that shares elements related to three domains: 1) to *knowledge* (to describe the system,

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definition of such a complex term as 'complexity.' Indeed, MIT's Seth Lloyd has gathered over 45 such definitions, most of these listed in Horgan ([*The End of Science*] 1997, Chapter 8, footnote 11, p. 303), with many of these definitions emphasizing computational or informational measures," BARKLEY ROSSER JR., J., "On the Complexities of Complex Economic Dynamics," *Journal of Economic Perspectives*, v. 13, n. 4, (1999), p. 170.

[29] SIMON, H. A., *The Sciences of the Artificial*, 3rd ed., pp. 183-184.

[30] Cf. RESCHER, N., *Complexity*: *A Philosophical Overview*, p. 22.

[31] Cf. *Complexity*: *A Philosophical Overview*, p. 9.

to produce it and to resolve problems within such system); 2) to *reality* itself both in the components (number of constituents and the variety of them) and in the structure (possible ways of arranging the interrelation of components and the modes of inclusion and subsumption in the relations of those components); and 3) to those *functions* that the system is able to develop (modes of operation and possible laws governing its way of functioning).

Therefore, the features of "complexity" are far beyond those emphasized by Simon, that of a mere hierarchical structure that is decomposable or near-decomposable, and that of a possible coordination that has also interrelations of constituents in order to evolve. A complex system —and, consequently, an economic system— involves at least several levels in its complexity: epistemic, ontological, and functional. Consequently, any economic prediction within a complex system should consider an array of factors. Because the possible large number of factors at stake, prediction should begin with something tractable: it should seek those factors that are more relevant, in principle, to cover the whole area of interest.

Those parsimonious factors should consider vertical components (such as hierarchy, open to modes of inclusion and subsumtion) and horizontal ingredients (such as coordination). From a graphical point of view, they can be depicted like few branches of a tree at the beginning that, starting from a finite set of elements, might be able to reach the whole sphera at stake. Economic prediction belongs to these complex cases where there are epistemological, ontological and methodological considerations. They receive the influence of past events (historical background), and those historical trajectories might have influence in order to describe the possible future and to guide the information needed for prescriptions.[32]

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[32] Cf. GONZALEZ, W. J., "Prediction and Prescription in Economics: A Philosophical and Methodological Approach", *Theoria*, v. 13, n. 32, (1998), pp. 321-345.

## 3. Prediction in Economics from the Perspective of Complexity

Unquestionably, complexity is a typical feature of economic reality. It is something directly linked to the character of human activity. This complexity in human affairs is different from that present in natural phenomena, such as the weather, which makes economic reality very difficult to forecast with accuracy and precision.[33] In the weather, in spite of the difficulties of knowing the variables in advance, these belong to a specific sphere: the physical one; while economic reality receives influences of diverse kinds of realms. In effect, there exists a wide spectrum of factors (ethical, social, political, psychological, biological, cultural, etc.) that affects economic reality as a human activity itself and as an activity connected with others.

To predict economic actions (individual or social) requires considering the diversity of influences that condition those actions. This goes beyond mere behaviorist conceptions (above all the comparison with the rats made by John Kagel)[34] to reinforce the *human* character of economic activity: we need the perspective of action theory. From this point of view, establishing the necessity and reliability of economic predictions —the core of the problem of prediction in economics— calls for clarifying the subject-matter of this science, i.e., a kind of human activity developed within a concrete sphere and connected with other human activities. The study of the components and features of economic reality needs to analyze the distinction between "economic activity" and "economics as activity."

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[33] Cf. GONZALEZ, W. J., "The Role of Experiments in the Social Sciences: The Case of Economics," in KUIPERS, T. (ed), *General Philosophy of Science: Focal Issues*, Elsevier, Amsterdam, 2007, pp. 295-298.

[34] The comparison with the rat is made by J. Kagel. Cf. KAGEL, J. ET AL., "Demand Curves for Animal Consumers," *Quarterly Journal of Economics*, v. 66, (1981), pp. 1-15. KAGEL, J., "Economics according to the Rats (and Pingeons too)," in ROTH, A. E. (ed), *Laboratory Experimentation in Economics—Six Points of View*, Cambridge University Press, Cambridge, (1987), pp. 155-192.

Unreliability is a consequence of the complexity of economic reality, but it is also something due to the insufficiency of econometric models (classic and time-series). a) There are difficulties in transforming qualitative aspects into quantitative ones, in order to introduce those elements in the variables of the model. b) Although a variable could be obtained, rigor in measurement is not always maintained. This inconvenience is increased by the difficulty of designing and conducting experiments in economics.[35] c) It is conceivable that with all the variables at hand a structural change might occur and, therefore, the mathematical calculus should be modified. (The economies of Eastern countries in Europe after the events of 1989 is a good example of this.) d) The uncertainty is the endogenous variables (in the classic econometric models) could be possible and besides that we need also to predict the exogenous variables.[36]

### 3.1. A Comparison with Prediction in Natural Sciences

Frequently, there is an insistence on the comparison with prediction in natural sciences, which compares economic predictions and predictions in physics. In this comparison, it is very common to assume that economics has both a lower knowledge of the reality that studies and a subject matter with a greater complexity than physics. Among others, Terence Hutchison used to emphasize the difference between economic and physical predictions: "economists cannot and will never be able to predict with the very high degrees of probability and accuracy which many natural scientists can achieve for their predictions."[37]

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[35] This assertion does not imply a denial of the possibility of experiments in economics, cf. GONZALEZ, W. J., "The Role of Experiments in the Social Sciences: The Case of Economics," in KUIPERS, T. (ed), *General Philosophy of Science: Focal Issues*, pp. 275-301.

[36] Cf. GONZALEZ, W. J., "Economic Prediction and Human Activity. An Analysis of Prediction in Economics from Action Theory," *Epistemologia*, v. 17, (1994), pp. 261-262.

[37] HUTCHISON, T. W., "On Prediction and Economic Knowledge," in HUTCHISON, T. W., *Knowledge and Ignorance in Economics*, Blackwell, Oxford, 1977, p. 10.

Hutchison sees increasingly important kinds of degrees of *interdependence* among economic factors, making economic prediction more difficult: a) in regard to market activity, and b) as between economic and social factors.[38] His position stresses fundamental differences between economics and the natural sciences.[39] At the same time, he emphasizes that economics is a science: "if all economic action or behavior was totally unpredictable, policy-making could only be sheer guess-work."[40] Thus, there are several aspects to be pointed out.

First, the difference between prediction in economics and in natural sciences is often clear, insofar as they often have a different degree of *regularity* of the events, due in part to the different degree of *complexity*. To some extent, regularity is a normal phenomenon in natural sciences (physics, geology, biology, etc.), in which the reproducibility of occurrences makes accurate predictability possible in many cases.

However, economic regularities are usually not derivable from "economic laws" (whose universality and even its existence are at stake).[41] In fact, some events in economics are completely unusual and even notoriously unexpected, like the great inflation of 1973 onwards, the

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[38] Cf. HUTCHISON, T. W., "On Prediction and Economic Knowledge," in HUTCHISON, T. W., *Knowledge and Ignorance in Economics*, p. 31.

[39] Hutchison considers that "in confronting and recognising such possibly serious difficulties looming over the future of economists' predictive performance and capacity, we are simply meeting up again with an aspect of the fundamental differences between economics and the more 'developed' natural sciences. Because of constancies in their basic materials, predictive capacity, once attained, regarding many physical or chemical phenomena, can be preserved, added to and accumulated to an extent significantly beyond what is possible in the social sciences. In economics and the social sciences it might well be that painfully and fleetingly achieved predictions and predictive capacity may not only lose practice relevance but may break down and even become more difficult to replace, because the basic material might be becoming more difficult, or impossible to predict," HUTCHISON, T. W., "On Prediction and Economic Knowledge," pp. 32-33.

[40] HUTCHISON, T. W., "On Prediction and Economic Knowledge," p. 9.

[41] Even the notion of "law" in economics is under discussion, cf. HAUSMAN, D. M., "¿Necesita leyes la Economía?," *Argumentos de Razón Técnica*, v. 3, (2000), pp. 115-137. The debate may be seen also in the context of the social sciences as a whole, where it is discussed if there can be laws of social science. In addition, it is commonly assumed that theories in the social sciences are less advanced than those of physics.

economic crash in the stock markets in October 1987, the economic turbulences after September 11, 2001, or the ongoing international economic crisis that started around the third quarter of 2007.

Second, *historicity* of factors that intervene in the economic predictions has a strong weight. It might be considered *prima facie* that the feature is not in itself something inappropriate for natural sciences (like physics, chemistry or biology), insofar as the temporal aspects are not irrelevant in them (or even, there is a "natural history"). However, there are differences between "temporality" and "historicity."[42] In addition, both kinds of sciences present a variance in the *type of link* between past and future events as well as in the "explanation" or "understanding" of what has happened and future occurrences: the link is usually weaker and more complex in economics than it is in natural science.[43]

Third, the notorious difference is —in my judgment— in the problems of *accuracy* and *precision* of economic predictions, because of the complexity of the factors that are studied in order to predict scientifically. So, even though chaos theory has shown an indeterminacy in natural dynamical systems which are usually deterministic, in economics —as well as in other social sciences— to predict is commonly more difficult than in natural sciences: there are more levels at stake in social events (as will be seen with the distinction between "economic activity" and "economics as activity").[44] In addition, some economists think that economics could be a chaotic system.[45]

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[42] Cf. GONZALEZ, W. J., "Caracterización del objeto de la Ciencia de la Historia y bases de su configuración metodológica," in GONZALEZ, W. J. (ed), *Acción e Historia. El objeto de la Historia y la Teoría de la Acción*, Publicaciones Universidad de A Coruña, A Coruña, 1996, pp. 25-111.

[43] This affects the features of "causality" in social sciences, an issue discussed by philosophers as well as by economists.

[44] Cf. GONZALEZ, W. J., "Economic Prediction and Human Activity. An Analysis of Prediction in Economics from Action Theory," pp. 262-280.

[45] This possibility is not denied by Simon. Cf. SIMON, H. A., "The State of Economic Science," in SICHEL, W. (ed), *The State of Economic Science. Views of Six Nobel Laureates*, p. 99.

### 3.2. Some Difficulties for Economic Predictions

Subsequent to the comparison between economic predictions and predictions in physics, it seems clear that the differences in the kind of subject matter have incidence in the role of prediction. They make the economic case usually more difficult than the physical one, and they affect the possibility of prediction itself as well as the question of its accuracy and precision. Besides the epistemological and methodological factors, there is an *ontological* element, which Amartya Sen has pointed out:

The notorious difficulties in making economic predictions —and especially making right predictions— "might be seen as resting on the fact, noted by Alfred Marshall, that 'no two economic events are exactly alike in all respects.'[46] This diagnosis does, however, slightly begs the question because, strictly speaking, that characteristic is shared by, say, physics as well (...). The real difference lies in the enormous variety of 'respects' that could actually make an important difference in economics, and the complex ways in which these economic influences operate and interact with each other."[47]

Besides the ontological element, there are at least two problems that concern intrinsic difficulties in social sciences: the *anticipation* of human actions and the *knowledge of the variables* that intervene now and in the future. Basically, the first problem is logico-methodological, which affects the possibility of predictions in social sciences, and it has received specific attention in the controversy over Popper's historicism.[48] The second

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[46] MARSHALL, A., *Principles of Economics*, 8th ed., Macmillan, London, 1949, p. 639.
[47] SEN, A., "Prediction and Economic Theory," in MASON, J., MATHIAS, P. and WESTCOTT, J. H. (eds.), *Predictability in Science and Society*, pp. 4-5.
[48] Cf. GONZALEZ, W. J., "La interpretación historicista de las Ciencias Sociales," *Anales de Filosofía*, v. 2, (1984), pp. 109-137. URBACH, P., "Is Any of Popper's Arguments Against Historicism Valid?" *The British Journal for the Philosophy of Science*, v. 29, (1978), pp. 117-130; URBACH, P., "Good and Bad Arguments against Historicism," in CURRIE, G. and MUSGRAVE, A. (eds), *Popper and the Human Sciences*, M. Nijhoff, Dordrecht, 1985, pp. 133-146; URBACH, P., "The Scientific Standing of Evolutionary Theories of Society," *London School of*

problem is epistemological, which has been emphasized many times as the main obstacle for the accuracy and precision of predictions in social sciences, in general, and of economics, in particular.

Regarding the first problem, the anticipation of human actions includes a wide collection of factors: social, historical, political, psychological and biological. They constitute a source of its complexity and have direct repercussions in economics. In the case of the second problem, the knowledge of the variables depends on access to the results of interactions of human beings: in economic affairs, they are dealing with each other with different values, objectives, motivations, expectations and circumstances.

Usually, all these elements together make prediction in economics more difficult than in the natural sciences. Specifically it is the case in *predicting the choices* of economic agents and in *predicting the results of interactions* of many human and social entities in a wide variety of ways. [49] Therefore, predictions in economics —especially quantitative ones— are frequently more difficult than in mature natural sciences.

Social sciences, in general, and economics, in particular, should look for specific predictions instead of seeking only generic predictions. In this regard, probabilistic predictions are especially important. They can be used as a tool for testing theories (in basic science) and as an instrument for public policy in applied science). The second case has more practical consequences in the context of the social setting.[50]

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*Economics Quarterly*, v. 1, (1987), pp. 23-42; and GONZALEZ, W. J., "The Many Faces of Popper's Methodological Approach to Prediction," in CATTON, PH. and MACDONALD, G. (ed), *Karl Popper: Critical Appraisals*, Routledge, London, 2004, pp. 78-98.

[49] Cf. SEN, A., "Prediction and Economic Theory," p. 5. Regarding the underlying problem, cf. BUCHANAN, J. M., "Is Economics the Science of Choice?," in BUCHANAN, J. M., *Economics: Between Predictive Science and Moral Philosophy*, Texas A & M University Press, College Station, 1987, pp. 35-50.

[50] It can also be connected to everyday life *conditional statements* like 'if we do X, then very likely Y will happen' or, 'if we do X, we will make Y's happening less likely.' In addition, there are also *counterfactual predictions*: 'if we had not done X yesterday, then Y would happen tomorrow' (or 'if we had not done X yesterday, then Y would *very likely* happen

## 4. The Role of Parsimonious Factors

When economic predictions are seen in the context of complexity, the search for parsimonious factors seems particularly important. The reason is clear: frequently, "radical openness and contextuality are properties that make the control and prediction of complex systems very difficult."[51] Parsimonious factors can be used for control of the system (i.e., to grasp "economic activity" and "economics as activity") as well as for prediction (including foresight and forecasting).[52]

In the sciences of design, such as economics, the role of parsimonious factors is related to two main methodological problems: (i) to obtain their *identification* as key elements of the system (i.e., as necessary and sufficient factors to understand the complexity of the system) and components that characterized complex adaptive systems (such as national economies or stock markets); and (ii) to state their *contribution* to that structural and dynamic system, which might develop new perspectives towards the future (i.e., prediction and prescription).

Putting it differently, there are two central epistemological and methodological issues at stake here: on the one hand, how to reach the parsimonious factors of a complex system, both in the configuration of the scientific framework and in the evolving dynamics of the discipline (in this case, economics); and, on the other hand, how to build up on the parsimonious factors in order to improve the system considered —structure and dynamics— and to enlarge it (e.g., in a science of the artificial, such as economics).

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tomorrow'). These kinds of predictions are relevant for public policy, even though they are hard to confirm and thus difficult for "science."

[51] CHU, D., STRAND, R. and FJELLAND, R., "Theories of Complexity. Common Denominators of Complex Systems," p. 28.

[52] On the distinction between "foresight," "prediction," "forecasting," and "planning," see GONZALEZ, W. J., "On the Theoretical Basis of Prediction in Economics," *Journal of Social Philosophy*, v. 27, n. 3, (1996), pp. 201-228, section 3.

### 4.1. Identification of Parsimonious Factors

How to get "parsimonious factors" is obviously the first problem. It is the task of identifying if there are "parsimonious factors" and which are then their relevant relations. This involves the assumption that there are components of the system that are really the central factors in its configuration. In this regard, "identification" is an epistemological-methodological procedure that includes at least three steps: 1) to be able of recognizing generators of complexity in the specific realm; 2) to grasp their nexus in order to establish the network of interrelations between generators of complexity; and 3) to arrive at the implications of the properties of those generators of complexity.

These steps towards the identification of the parsimonious factors in a complex system require taking into account several approaches. Among the classical forms of analysis are the following four kinds: hological, etiological, teleological, and logical. (i) Hological analysis is when a whole is divided in its different parts; (ii) etiological analysis is carried out when there is a search for causes and its presumptive relations with effects; (iii) teleological analysis is developed when the relation is established between means and ends regarding to a given system; and (iv) logical analysis is when the relations are studied in connection with conceptual contents.

Hological analysis is done by separation of components. Through this "top-down" analysis we can get an internal inhomogeneity of the system. Simon's conception on "architecture of complexity" as well as his views on "near-decomposability" fit quite well within the hological analysis.[53] His study of the parsimonious factors in complex structures of the sciences of

[53] "One of the important properties that we observe in virtually all complex systems, whether they be social, technical or natural, is that they are nearly decomposable. This means that each such system is divisible into parts, with a high density of interaction among the elements within each part and a lower density of interaction between these elements," SIMON, H. A., "Organizing and Coordinating Talk and Silence in Organizations," *Industrial and Corporate Change*, v. 11, n. 3, (2002), p. 611.

the artificial are made following the division of a whole in its parts. He gives more weight to ontological considerations than other philosophical reflections.

Etiological analysis is the search of causes in the system, mainly those causes that may have multiple effects. "Causality" has received a lot of attention in social sciences, in general, and in economics, in particular. Its possibility in this realm as well as its characteristics[54] (either similar or different in comparison with the natural sciences) have been discussed. What is commonly assumed is the high connectivity of the parts within the economic system. If we can get ontological causes (i.e., actual and effective) or epistemological ones (i.e., according our present knowledge) in the economic system, there are important advantages for prediction.

Teleological analysis is focused towards the dynamics of the system. Commonly, there is a relation between means and ends within a system, which could be synchronic or diachronic. This relation means-ends is also open to the etiological analysis. De facto, there are studies that "attempt to distinguish between system linkages at a point in time (synchronic) and linkages between things as time passes (diachronic): if a subsystem were subject to a shock, the structure of the former linkages could affect the set of events that then unfolded through time."[55]

Frequently, when the emphasis means-ends is on the dynamics of the system, the characterization in the case of economics is seen as an *evolution*. Then, economic dynamic understood as an "evolution" appears as a creative and destructive process, which shows the historical component

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[54] See for example BROCK, W. A., "Causality, Chaos, Explanation and Prediction in Economics and Finance," in CASTI, J. L. and KARLQVIST, A. (eds), *Beyond Belief. Randomness, Prediction and Explanation in Science*, CRC Press, Boca Raton, FL, 1991, pp. 230-279; and ENGLE, R. F. and WHITE, H. (eds), *Cointegration, Causality and Forecasting: A Festschrift in Honour of Clive Granger*, Oxford University Press, Oxford, 1999.

[55] EARL, P. E. and POTTS, J., "Bounded Rationality and Decomposability: The Basis for Integrating Cognitive and Evolutionary Economics," in AUGIER, M. and MARCH, J. G. (eds.), *Models of a Man: Essays in Memory of Herbert A. Simon*, The MIT Press, Cambridge, MA, 2004, p. 323.

of economics. Thus, there are changes of different kinds in the relation between means and ends: a) most of them are originated in the system; b) some are modifications as the result of connections between systems; and c) others are the consequence of emerging new systems. [56]

Logical analysis is oriented towards the search of parsimonious factors as "central statements" of the system considered. These statements might be understood as "basic principles" of the whole set of relations established in the system. This analysis avoids the interest in simplicity and looks for the common denominators of the complex system. If they are found, then they may be used for the search of other properties within the system. In addition, these parsimonious factors from the logical point of view can be utilized to enlarge the system in a coherent way (i.e., as "bottom-up" analysis).

Using this set of analyses —hololological, etiological, teleological, and logical— the identification of "parsimonious factors" of a system could be obtained. Thereafter, the relevant elements for economic predictions of that system should be easier. In this regard, a convergence among the results of these four analyses is expected, because the main elements (parts, means, causes and reasons) might be connected in order to clarify the parsimonious factors of the structure and dynamics of the system considered. Moreover, the complex configuration of past events and their evolutive dynamics (such as the Great Depression of 1929 and subsequent economic phenomena) can offer some lessons that can be used for the analysis of present events (the ongoing international economic crisis) and their projection towards the future.

### 4.2. Contribution of Parsimonious Factors

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[56] EARL, P. E. and POTTS, J., "Bounded Rationality and Decomposability: The Basis for Integrating Cognitive and Evolutionary Economics," in AUGIER, M. and MARCH, J. G. (eds.), *Models of a Man: Essays in Memory of Herbert A. Simon*, p. 328.

If the identification of parsimonious factors pays special attention to past and present aspects of the complex system, the second problem —how to build up on the parsimonious factors— is principally oriented towards the future. This is particularly important in a science of design such as economics, because it is an applied science that uses prediction as an indispensable ingredient for making prescriptions.[57] In this task of modeling systems towards the future, there are a number of difficulties, among them is the absence of a "comprehensive theory of design" elaborated around central constraints.[58]

From a hological perspective, there is a transition from analysis to synthesis. This movement from parts to wholes has been central in Simon's perspective, which thinks that "the whole is (sometimes) many times more than the sum of its parts."[59] If this is the case, then it is clear that there are "intrinsic difficulties with representing complexity in computer models."[60] Moreover, it seems reasonable to accept in economics the existence of nonlinear interactions between parts of the system. Thus, in order to build up on the parsimonious factors, we need elements serving organized complexity, such as hierarchy. In this regard, Simon has pointed out: "all business organizations are hierarchies, where the hierarchy denotes not only relations of authority, but some degree of independence of each unit and subunit."[61]

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[57] Cf. SIMON, H. A., "Prediction and Prescription in Systems Modeling," *Operations Research*, v. 38, (1990), pp. 7-14; reprinted in SIMON, H. A., *Models of Bounded Rationality*. Vol. 3: *Empirically Grounded Economic Reason*, The MIT Press, Cambridge, MA, 1997, pp. 115-128. Cf. GONZALEZ, W. J., "Prediction and Prescription in Economics: A Philosophical and Methodological Approach", pp. 321-345.

[58] Explicitly, Simon recognizes that "I should like be able to present to you a comprehensive theory of design built around this central constraint [the scarcity of attention]; but lacking such a theory —and I certainly don't have one— ...", SIMON, H. A., "Organizing and Coordinating Talk and Silence in Organizations," p. 614.

[59] SIMON, H. A., "Organizing and Coordinating Talk and Silence in Organizations," p. 612.

[60] CHU, D., STRAND, R. and FJELLAND, R., "Theories of Complexity. Common Denominators of Complex Systems," p. 20.

[61] SIMON, H. A., "Organizing and Coordinating Talk and Silence in Organizations," p. 612.

Building up the system with the etiological approach requires the acceptance of "causes" in human affairs,[62] both in the social sciences and in the sciences of the artificial. Simon accepts a causal relation that links phenomena in an asymmetric way. For him, this causal relation is "a functional relation between variables, not a logical implication between the values of those variables."[63] His interest is in parsimonious factors: "we necessarily restrict our analyses to events of small or middle-size worlds, abstracted from their larger environments and characterized by very small number of equations. We see that the notion of causal ordering provides us with a rigorous justification of this essential practice."[64]

Causality in dynamic systems is analyzed by Simon from the point of view of a system that is composed by subsystems, where the principal strong forces connect variables belonging to the same subsystems. The dynamics of the nearly decomposable system might be in the short term (the interest is in the relative movements of the variables in each subsystem) or in the long term (the dynamics is then associated with the linkages between subsystems). Thus, "at any level in the hierarchy, the causal ordering that relates to the relative movement of the variables *within* any single component is (nearly) independent of the causal ordering *among* components." [65]

Certainly, this kind of approach is also related to a teleological analysis. In the case of economics, complex systems such as organizations and

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[62] Cf. SALMON, M. H., "La explicación causal en Ciencias Sociales," in GONZALEZ, W. J. (ed), *Diversidad de la explicación científica*, Ariel, Barcelona, 2002, pp. 161-180.

[63] IWASAKI, Y. and SIMON, H. A., "Causal Ordering, Comparative Statics, and Near Decomposability", *Journal of Econometrics*, v. 39, (1988). Reprinted in SIMON, H. A., *Models of Bounded Rationality*. Vol. 3: *Empirically Grounded Economic Reason*, The MIT Press, Cambridge, MA, 1997, p. 18.

[64] IWASAKI, Y. and SIMON, H. A., "Causal Ordering, Comparative Statics, and Near Decomposability", in SIMON, H. A., *Models of Bounded Rationality*. Vol. 3: *Empirically Grounded Economic Reason*, p. 25.

[65] IWASAKI, Y. and SIMON, H. A., "Causal Ordering, Comparative Statics, and Near Decomposability", p. 35.

markets are "goal-oriented activities."[66] Moreover, they can be seen as the principal organizers of most of our collective intentionality and with a historical development. Again, we can use parsimonious factors: in the case of short-term, middle-term and long-term economic phenomena, "attention can be directed to the dynamics of specific subsystems without dealing with the entire system at one." [67]

Logically, parsimonious factors cannot be used as an "automatic deductive system". They include elements that are interconnected. Thus, in the realm of microeconomics, there are links between uncertainty, bounded rationality and prediction. Economic prediction cannot be made on the basis of a "perfect rationality," because there are *limitations*: the uncertainty about the consequences that would follow from each alternative when a decision is made, the information about the set of alternatives could be incomplete, and the complexity of the situations can prevent us from doing the necessary computations to solve the problem.[68]

Thus, against neoclassical positions —mainly, those of Friedman—,[69] Simon maintains that "in this kind of complexity, there is no single sovereign principle for deductive prediction."[70] For him, the evidence available reveals that a theory of substantive rationality and the assumptions of utility maximization do not provide a sufficient base for

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[66] SIMON, H. A., "Complex Systems: The Interplay of Organizations and Markets in Contemporary Society," *Computational and Mathematical Organizational Theory*, v. 7, (2001), p. 79.

[67] "Causal Ordering, Comparative Statics, and Near Decomposability", p. 40.

[68] Cf. SIMON, H. A., "Theories of Bounded Rationality," in MCGUIRE, C. B. and RADNER, R. (eds), *Decision and Organization*, North-Holland, Amsterdam, 1972, p. 169.

[69] Friedman has been very influential in mainstream economics. He has emphasized the idea of predictions about phenomena not yet observed as the ultimate goal of a positive science (Cf. FRIEDMAN, M., "The Methodology of Positive Economics," in FRIEDMAN, M., *Essays in Positive Economics*, The University of Chicago Press, Chicago, 1953, 6th repr., 1969, p. 7). His idea is focusing economic theory on valid and meaningful predictions, which highlights the "impersonal" results, whereas Simon stresses the role of understanding processes and human behavior.

[70] SIMON, H. A., "Rationality in Psychology and Economics," in HOGARTH, R. M. and REDER, M. W. (eds), *Rational Choice. The Contrast between Economics and Psychology*, The University of Chicago Press, Chicago, 1987, p. 39.

explaining and predicting economic behavior. Therefore, he suggests applying the procedural theory of rationality to economics, both at micro and macro levels.

Therefore, in order to tackle with the problem of complexity, the parsimonious factors cannot be reduced to "near-decomposable" elements in a given system and their evolution. If they want to be the necessary and sufficient elements to reach the whole system, parsimonious factors should take into account the four levels pointed out. When they are used for economic predictions, those factors should give us the ontological elements (parts or phenomena), epistemological components (causes), methodological requisites (processes valid for development) and logical aspects (reasons) that are relevant for foretelling events in the economic realm (e.g., about the future of the financial crisis).

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