THE COMPLEXITY, THE SYSTEMIC THINKING AND THE VALUE OF ECONOMIC REALITIES OF THE XXITH CENTURY*

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The need to structure the complexity science was made in July 1991, in Physics Today by Philip Anderson, a professor at Princeton University in the U.S., in the article *Is Complexity Physics? It is a science? What is it?*. Over time, it began to shape the subject in new ways other than the previously used classic methods. In such a context, the book *The Economic Complexity Paradigm*, appeared at the prestigious publishing house Expert, developed by my colleagues Ion Popescu and Laura Ungureanu, outstanding researchers and analysts of the phenomenon and authentic Romanian teachers in higher education that bring a notable contribution to the concept's development and assimilation in the economic theory and practice. From this perspective, the tasks faced by economists, engineers and managers are so extensive, contradictory and restricted that they require more comprehensive knowledge in various areas, especially in terms of economic modelling and using mathematical research methods.

The Economic Complexity Paradigm represents a genuine interdisciplinary work, based on bifurcation theory, which is distinguished by clarity and the sharp thinking of the authors. The theme is interesting and topical. The area where non-linear dynamics and bifurcation penetrate and grow today is the economic and biological evolution itself. Even the chosen models seem relatively feasible, they proved to be very complex and extremely difficult to examine. It's been checked again that most times, the simple models are very complicated because of their nonlinear dynamics. Therefore, by deep and complete treating of mathematical models from economy, the authors approach is a pioneering work in the economic dynamics. However, the results and conclusions of the authors are mainly theoretical and numerical by nature: some are very difficult to

* Review on the book: I. Popescu, Laura Ungureanu, *The Economic Complexity Paradigm*, Expert Publising House.

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obtain, involving refined analytical and geometrical methods that have to take into account the frequent dynamic changes for small parameters changes, the balances and their own values transformations, also caused by parameters variation.

We should make some clarifications, as follows:

Thus, in *Section 1.1.* is treated the issue of the link between development, growth and progress. Further, are presented one by one the passage from static to dynamic, from balance to imbalance, from stability to instability. The issue of economic cycles – as evidenced in various forms – is developed in *Section 1.5*. The emergence of complexity sciences and their use in the study of economic developments are discussed in *Section 1.6.* as rightly indicated by the authors, a new approach to economic development has emerged in the '70s when all countries faced many difficulties, although they work hard to industrialization. The realistic specialists in contemporary economic problems had to warn the public and other economists that too many things go wrong, either in the sense that there is too much violence and little economic rationality (R. Kothari – 1974) be it in the fact that the development efforts of many hundreds of millions of people are wiped out due to *structural violence* (Galtung J. – 1980) or that the excessive division of labour and exaggerated specialization in some areas have started to slow, even make irrelevant, the current economic mechanisms (P. Hawken – 1984). Otherwise the evolution of economic thought from static microanalysis to dynamic macro-analysis was a real progress in the economic science. Vision of society's economic movement began to approach more to the conception of living organism's movement, the human society representing a complicated self-propelled body. As the emergence of global, planetary problems that influence the growth processes, the national, regional or global development, such as the depletion of non-renewable natural sources, population structure, deteriorating natural environment, technology development, the issue of food, excessive urbanization, economic underdevelopment, and the political economy has led to the investigation of many theoretical and especially practical issues for evolutionary economics. In general, the economic processes by their inertial nature have an intrinsic continuity; the jumps are exceptions to the rule. If these jumps exist and generate discontinuities, which is the reason to know them as intrinsic phenomena, but especially due to the propagated effects, as it is known that small disturbances by amplification can lead to large, sometimes catastrophic effects.

The *second chapter* presents the initiated necessary theoretical study (notions and results from the dynamical systems theory and bifurcation

presented in a unified form that highlights both their utility and how to apply in concrete situations). On the other hand, after study context and methods used, the static bifurcation theory belongs to the nonlinear functional analysis and to the singularities theory. The static bifurcation and determining the location of bifurcation branches of stationary solutions that goes from that point. Finally, for the dynamic bifurcation, should be classified the types of local issues for the phase portrait. Indeed, this local portrait is analogue to the local image of the crowd stationary solutions of an equation. For this, the dynamic systems crowd must be divided into classes of equivalence: i.e. stable, unstable or junction crowd.

In the *third chapter*, consulting a large number of literature works, the authors imagine and develop fifty-five economic models given by the dynamic systems. For most of them are presented the mathematical results and the economic interpretations from the literature. The patterns of economic growth and economic-mathematical modelling practice constituted an opportunity and a tool for studying the imbalances in the contemporary economy, stimulating discussions on economic cycles and different kinds of crises that have occurred over time.

Generally, the growth models assumes self-balancing market economy hypothesis through price fluctuations. In other words, they aim to optimize the use of production factors, including their mutual substitution in certain limits.

These models explain the economic growth (products and income growth) through the combined contribution of two production factors: the capital (K) and the labour (L). Economic growth is the result of productive services to the two production factors, the results being expressed in physical or natural units.

The dynamics and growth rate depends on two different factors: on the one hand, the rate of capital accumulation and investment (i.e. increasing K), and on the other hand, the technical progress (which allows the reduction of variable L as result of increased labour productivity). As known, the capital is a major factor of modern market economy functioning. The capital importance is that by using it considerable increases the efficiency (productivity) of work. The longer the period of production, the production tools are made more complex and efficient, with much greater influence on future work, which becomes more fruitful.

The starting point of analytical instruments used by the growth models is Cobb-Douglas production function (1929), which expresses the simplified relationship between quantity and the combination of two factors of production (K and L) and the obtained result, either as

production growth (Q), either as income growth (Y). Therefore, in the first studied model in the equation of evolution of firm capital (trader) the authors opted for the production function Cobb-Douglas type, in which was considered the production growth stronger than the increase of other factors, as a result of increased efficiency (characterizing the most dynamic areas of activity).

In the next segment, respectively the *fourth chapter* is studied such a model governing the dynamics of capital and labour resources in a company. Initially, the model has nine real parameters, but after changing some unknown functions, it remains with only three parameters; the vector field is polynomial third degree in the first equation and first degree in the second. The theoretical results obtained for this model were validated by computer numerical investigations that used some special software packages (Maple software and Xpp).

Section 4.1. refers to the static bifurcation diagram. By agreed changes of the functions, of the unknown and parameters they managed to reduce the number of parameters from eight to only three. This reduction results in highlighting some economic expressions, functions of the primary economic parameters involved in the evolution of capital and work resources (labour) in a company. Thus, the same value of a new parameter corresponds to a large variety of values for old economic parameters, in this way forming classes of equivalent economic situation. Since the static bifurcation diagram has been reduced to a four-dimensional one, the graphic investigation was done by investigating its sections, focusing on a portrait of parameters which, in the first instance, take into account only the equilibrium points corresponding to the transitional economic developments that are very much influenced by the presence of these balances, whether they are attractive, repulsive or attractive crowd situations, corresponding to the existence of a single point of equilibrium, of two or three equilibrium points. For their usefulness in the study of bifurcation, were analyzed cases in which at least one of the three parameters is zero. In most cases, was even given the explicit form of the dynamics. In all cases it's been studied the topological type of equilibrium points; in Section 4.1.5. all these results were combined and completed to obtain the overall picture to the existence and nature of equilibrium points when at least one of the parameters is zero. Lower edges of the corresponding dynamical systems co-dimension have been evaluated taking into account the variation of parameters on the axes of coordinates, the coordinate planes and all the parameters space. So was prepared the switching to the dynamic bifurcation study and to the case when all parameters are nonzero.

Section 4.2. is dedicated to this case, namely to the static bifurcation diagram of the three nonzero parameters. Although we have the explicit expressions for the equilibrium points and their associated values, the static bifurcation diagram study and, in particular, the parametric portrait (partial) is difficult because of the appearance, disappearance and change of the topological type of equilibrium points depending on the parameters values. Accordingly, in the parameter space appear crowds with a very complex geometric structure. Therefore, in this chapter, the authors have done well to focus on the geometric study of different varieties, especially two-dimensional, where are located the corresponding parameters of a given topological type of an equilibrium point. The most difficult situations are those where, for the same parameter, there are several equilibrium points, of which one, two, or three are non-hyperbolic. For the ease of study, is investigated the topological type of balance of the parameters plane space passing through the axis Oc (c is one of the parameters), with the planes sweeping all parameters space. This allows finding a partial parametric portrait highlighting the Hopf bifurcation surface values (possibly degenerate) and Bogdanov-Takens curves of bifurcation values.

Section 4.3. studies the local dynamic bifurcation around the non-hyperbolic equilibrium points, related to the limit cycles occurrence of equilibriums. The limit cycles in the parameters space correspond to the economic cycles, i.e. periodic economic dynamics. They are of great importance in the economy and therefore their highlight is very important. So there are many situations that gain meaning, situations on the emergence or, conversely, the extinction of limit cycles and thus of the periodic economic dynamics: the Hopf and Bogdanov-Takens type. It also shows that in some cases, the existing theories (usually expressed by sufficient conditions of existence) cannot be applied to the investigated model, resorting to direct numerical calculations.

The chapter ends with the assessment of the complexity of economic development dependence of the parameters in form of numerical applications.

The *fifth chapter* is dedicated to a similar study for another two-dimensional model of economic dynamics that is one of advertising. In the study of this model, is found “the advertising spiral”, frequently invoked by economists, confirming again the accuracy of the used methods and their usefulness for economists. Thus, *Section 5.1.* describes a mathematical model of advertising which has two state functions, four real parameters and cubic nonlinearities of the vectors field. One of the parameters models the market penetration rate of new customers. If this is

zero (*Section 5.2.*) then is made a study of static and dynamic bifurcation. When different from zero, it means that the transformation of the state functions and parameters leads to a dynamic system depending on two parameters (*Section 5.3.*) with which is built the static and local bifurcation diagram of the dynamic bifurcation as an economic interpretation of the results.

We note the consistency of numerical results with the real economic situations, which proves the importance and effectiveness of the proposed approach. Thus, by means of the dynamical systems the authors highlyghted the cyclic evolution with the four specific classic moments: crisis, depression, resumption and expansion.