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ECONOMETRICS MODELS VERSUS PHYSICS MODELS AND THEIR FINAL CONECTIONS WITH SOCIAL ECONOMIC REALITY, THE EDUCATIONAL SYSTEM AND SCIENTIFIC RESEARCH

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Abstract. *Research today becomes impossible without a special way of thinking and modelling the reality as an object with more and more dimensions. From the great diversity of sciences, the importance of the concepts of models in mathematics and economics has been emphasised by the complexity of contemporary scientific research, which has made them evolve, in an interdisciplinary manner, along at least five directions: the econometrical models, the econophysics models, the sociophysics models, the quantum economics models, and the science of complexity models. The new way of thinking the continuity of the natural processes using models from physics, apparently forgotten in point of the importance of its proximity to the nature and reality, seems to be decisively prevalent in the new scientific researches forming new many domains of activity, belonging to the vast field of the quantifications of progress in social economic reality. The physics models used in econophysics or sociophysics do not analyze only economic or social processes and phenomena, but rather their continuity in evolution or involution. The authors of the present paper propose a different approach to the modelling process, a new systemic approach which involves new attitudes, ranging from acknowledging the differences between mental or intellectual models of econometrics and experimental models of physics, to repositioning the educational system, as well as scientific research. Finally, the paper illustrates, through the new paradigm of an apparent conflict between the two species of models, an old dispute between mental and experimental attitude in scientific research and academic education.*

Keywords: *mental model, experimental model, econometric model, econophysics model, sociophysics model, quantum economics model, science of complexity model.*

Introduction

If René Descartes identified thought with conscience, and considered it a necessary prerequisite of man, especially of the researcher and the teacher, asserting, with seeming simplicity his famous *I think, so I exist*, modern thought,. As a reflective process, has gradually acquired a mediated character through the agency of the relational and law-like model playing between objects and phenomena that are external to themselves, generalized though its specific operations, essentialized as a type of specific organization of information, and abstract through its results turned into concepts, reasonings, methods and even theories. Parting, as a special object, with research, scientific thought must be considered a *holos*, or a well-articulated system. The generic attribute of a system is conferred by the fact that it comprises far more than the mere summation of the set of elements making it up, in reality (information, operations, hypotheses, etc.), which are relatively distinct and correlated in a random manner. Scientific thought, by restructuring reality through a coherent system of signs and symbols, detached from the objects and concrete images, exhibits a twofold dimensionality, through *projectivity* and *hypotheticity*, thus shaping the action within the realm of abstraction, of possibility, of a non-contradictorial future. The model, therefore, remains the essential substance of thought, in its distinct forms of a mental or experimental model, of an analytical or synthetical model, of an inductive or deductive model, etc. Scientific thought only appears when at least three essential elements are combined, i.e. a distinct theory, a segment of the reality considered as its object of study, and a model of going between the theoretical investigation and that study object. A process of modelling is a mentally innovative one, or a continuously experimental model. At present, the model is simultaneously recognized as a method, and a component of the constitutive triad of scientific thought, or of sciences themselves (theory–model–object of study).

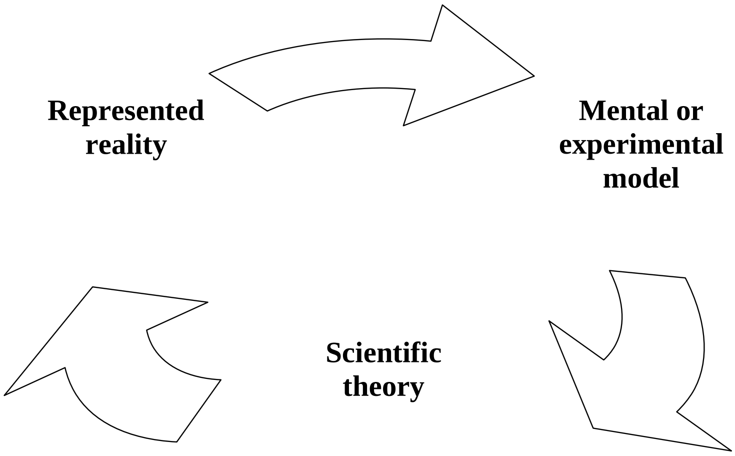

Figure no. 1. **The continuous process of modelling in classical and modern scientific thought**
Source: Săvoiu G., Iorga-Simăn I., *Multidisciplinary modelling knowledge, and one-discipline isolation*, in *Exploratory Domains of Econophysics. News EDEN I & II*, Ed. Universitară, Bucureşti, 2009, p. 74-75

The analytical model-based approach starts from the hypothesis according to which understanding each separate detail of the model conduces to correctly perceiving the phenomenon quantified and theorized, in its wholeness, and, at the operational level, it leads to the primordiality of the parts in their relationship to the whole, since it is considered that as long as each component of the model, or of a whole, is perfect, the model or the whole thus obtained through their aggregation will also function perfectly. This approach generates the fragmentation of a mathematical type, apt to model reality, which is to say the mental linguistic or mathematical model as major expressions of modelling as a process. Alfred Marshall specified, in an inimitable manner, that *the mental model is the model that needs "three great intellectual faculties – perception, motivation, but mainly imagination, in order to intuit and connect the direction of events that are placed wide apart, or are to be found under a perceivable surface, having causes and effects that lie at a similar distance, or under the same surface."* The mental model represents our profound understanding of a portion of reality itself, which we have rendered conscious rather theoretically than methodically, and is consequently experimental. Any mental model has to be flexible, in the sense that the reality studied or synthesized is reconsidered as a domain of information extended beyond the numerically limited universe, or in other words beyond the mere mathematical model, thus becoming a filter through which reality can be interpreted, one can rationally act on reality, and especially one can select, in a well-grounded manner, and according to an optimal prognosis, the solution or variant for action best suited to the respective situation. In a certain sense, all that differentiates and consolidates the idea of logical, philosophical, mathematical, physical, economic, etc. thought can be identified and redefined, in turn, through the specific concept of the mental model. There are disadvantages of a general character inherent to virtually all the mental models (from the comprehension difficulty, to the subjectivity of their interpretation, from their imperfection as a methodology, to their lack of completion in point of covering reality, etc.), and also specific disadvantages (such as the names given to the components of reality, bearing the sense of symbol-words, as an instrument of knowing the permanent and invariable essence of things in the linguistic model, or in the manner in which minimality and non-contradictoriality appear in the logical model, etc.). Famous within the vast area of thought, the problem of the circularity of the formal systems finds that the wish to express knowledge in a formal manner is illusory, and that there are, in the main formal logical systems or in the related systems, relatively simple assertions or theorems, which cannot be solved within the system in question, as the respective assertions or theorems in the model analyzed are neither demonstrable, nor non-demonstrable (the famous problem of Gödel).

Entirely opposed to the mental model, the experimental model gives priority to the idea that the reality studied as a system or a whole, represents more than the sum total of its parts, as the experiment continuously provides corrections to the aggregated real, as a support of the modelling. The experimental model completely characterizes the thought of physics, and proves it is much closer to nature or to reality. The solution offered by the physical models tries to elude the question of ambiguousness or contradictoriality, through its continuous experimental rectification, and felicitously ensures the completeness of modelling through minimality, by returning to nature or to reality, in a continuous, non-speculative manner, which is on the contrary interrogative in the sense of validating the hypotheses of physical knowledge. Though apparently not dominated by the details, the physical model is much able than the other specific scientific models to reconsider their importance through the process of validation/invalidation of their hypotheses by means of experimental thought.

The modern econometric model, a synthesis of the statistical, mathematical and economic models

The concepts of model and modelling represent the elements through which every single science is discriminated and individualized, so they call for a special treatment. Are the model and modelling in econometrics to be singled through special aspects concerning the application of statistical-mathematical methods, instruments and techniques to the economic problems, which is, through a conglomerate of notions extracted from the three sciences put together.If, by means of econometric modelling, new hypotheses are verified, and new economic theories are developed, and starting from the new knowledge thus generated the experts proceed to design simulations or grounding s number of decision-making models or models for implementing the economic policies, the phenomenological diversity becomes the cause of a multiplication of the models, in a continuous process. In keeping with the reason of being of the model, as a rendering, or maximal fidelity translation of reality, any theory corresponds to a model, and any models, validated via the study object of the respective science, will correspond with the reality. The fact is that the more sciences are to be found at the intersection determining the very essence of the model, the more correct the rendering. Identifying a sole answer to the question "what is a model?" represents a difficult undertaking and it needs various, many-sided approaches. Three variants can be enumerated in order to give the whole idea of an econometric model:

- in the economic opinion, the model remains the instrument of solving a set of general problems, and modelling represents either a sequence of means aimed at revealing the real nature of the problems of economic theory, from those relating to the national wealth to those connected with earmarking insufficient resources, or a simplified image of the relationships between the economic variables, which comes close to the structural-anatomical representation of the economic processes (defining variables) and the physiological description (relationships, conditioning, functional mechanisms);
- from the angle of mathematics, the model overlaps on a certain type of measuring methods specific to research in mathematics, meant to objectively explain the manner in which the micro-components and their interactions, interpreted individually or grouped in subsystems, generate and explain the whole system (Octav Onicescu and the model of informational energy), to define and describe, in a non-contradictorial manner, processes and phenomena, theses, postulates, axioms, and their logico-mathematical correspondence (expressed in mathematical symbols, with mathematical concepts, by describing the relationships that are instituted between the variables and the own parameters of a reality under study);
- in its statistical meaning, the stage-ordered sense of the concept of model is that of a link belonging to an integrated knowledge process, being made up of the hypothesis, the schematic representation of a process (phenomenon), the statistical testing of the hypotheses formulated on the reality studied, and the repeating of the process in a general theory.

The econometric model relatively exceeds both inter- and trans-disciplinarity, and opens up the horizon of multiple disciplinary collaborations, tending towards the multidisciplinary model. In constructing the econometric model, some dominant elements in the mental or theoretical model can be noted: a) the primacy of theory, as Louis Pasteur elegantly underlined, via his well-known formula: "*chance favours only the well-trained minds*"; b) the "*dogmatics of isolation*" of the model, once constructed, in relation to the initial reality that generated it – as Tiberiu Schatteles put it synthetically while likening scientific thought and modelling itself (to illustrate a phenomenon, scientific thought isolates it from reality, or contingency); c) defining the framework in the modelling isolation, through postulated or axioms such as "*something that goes without saying*" completes the study of a phenomenon in a state of isolation; d) the option for a complex iterative process of modelling, either in simplified variants of the type of the "*triad*" (the formulation of a hypothesis, collecting the experimental material, and verifying the hypothesis), or in excessively detailed variants (formulating the initial model, while forming classes of repartitions, culling the data, choosing a particular repartition, verifying the degree of concordance of the repartition chosen with the real situation, and formulating the hypotheses that explain the random mechanisms that generated the data, etc.).

In dependence on many factors, starting with the quality and the volume of the data, and up to the competition between the models, generated by its application, the econometric model is a way of confronting the economic theory with practice, the only way through which the science of economics can found its hypotheses, since its object of research can be only observed, not isolated and researched in a laboratory. The model, in its turn, becomes an essential factor of the research. Finally, the econometric model redefines the science of economics, reconsidered, in John Maynard Keynes' opinion, as "*the science of thinking by means of the models, combined with the art of choosing the relevant models*". The econometric model is regarded either as a *simplified and formalized presentation of a phenomena in the shape of a number of equations in which the variables are economic entities*, thus becoming an *instrument that helps to understand and explain the phenomena in economy*, either as a result of the *application of a number of econometric techniques with a view to determining the most probable manner of conducting business* (the model in Popper's approach), or it represents, between certain limits, *significant modalities of analysis and prevision in economy* (the model in Lucas's vision), etc. As can be noted, it is hard to define, in a general or universally accepted manner, but the idea can be put to use that the econometric model represents a really descriptive or normative instrument, a conventional and simplified image, which is isomorphous (possessing the same structure), homomorphous (possessing the same form) and/or capable of rendering the same relationships within, or without, the object (phenomenon, process, system), or the economic reality as a whole, which are submitted to the research.

The econometric model also represents an aggregate of the conceptual, instrumental contributions, of the techniques and methods specific to statistics, mathematics and economics. Econometric modelling thus becomes a set of quantitative techniques and methods, which are useful to construct essential econometric models in the process of making economic decisions. *The econometric model represents represents an operational methodological complex, a chain of activities, a sequence of stages and intermediate stages, which define it in point of make-up, and where not only statistics or mathematics, but also economics have significant, concrete contributions for each step of the modelling.* The econometric modelling process, whose avowed aim, it is to illustrate the complexity of such an undertaking, but also the fascination exerted by it on those who design it, compels a survey of its extended stages, and also of its chief aspects concerning the concrete process of its construction:

Box no. 1

The stages of classic econometric modelling	The stages of modern econometric modelling
I.Supplying the series of statistical data *II.Theoretical elaboration of the econometric model* (sub-stages) 1. Identifying the model 2. Specification of the model 3. Assessing the model 4. Verification of the model *III.Making the econometric model operational* (sub-stages) 1. Analyses of the model 2. Use of the model in prognoses 3. Use of the model in simulations *IV.Supplying updated series of data* *V.Confronting it to the reality*	*1.Reviewing the theory in the field the phenomenon under research belongs to* *2.Presentation of the theory the econometric model is grounded by* *3. Supplying the series of statistical data* *4.Estimation of the econometric models* *5.Empirical results* *6.Decision concerning the test of the statistical hypotheses* *7. Decision concerning the test of the model on the whole* *8.Validation or invalidation of the model (taking over points 2,3,4,5,6,7)* *9.Conclusions and impact on the theory existing previous to the modelling*

Source: Săvoiu G., Necşulescu C., (2009), *Econometrics* Ed. Universitară, Bucureşti, p. 49-50

The detailed presentation of a stage is much more extended in the modern econometric model. An example in this connection can be illustrative. Here is a description of some potential sub-stages that complete the manner in which *supplying the series of statistical data:* a) selecting and operationalization of the variables; b) selecting and operationalization of the measuring scales, defining the statistical population (implicitly the units, defining and rendering concrete the access to the statistical units bearing the information); c) defining the statistical range of specimens (research is seldom exhaustive); d) construction and theoretical validation of the research instrument (questionnaire, interview, etc.); e) ensuring a pilot test concerning the research instrument; f) final validation of the research; g) applying the research instrument to the statistical range of specimens; h) analysis of the poll data, and formulating the conclusions of the stage, etc. The process of econometric modelling can however be detailed to excess, starting from the more and more complicated investigation of data sets of increasing size, resulting from the development of the informational market, of the communication networks, of the decision-making databases, of the general informational explosion.

Two of the main initial objectives of the classical econometric model remain valid even today: *achieving empirical* (quantitative) measurements necessary in the economic theory, and *verifying the economic theory* by means of the tests, finalized through decisions of validation or invalidation of some important theoretical components. Modern econometrics redefines as objectives: *identification of the variables, testing the statistical hypotheses, and foreseeing the economic phenomena.* Any economic theory is concerned with defining its interest characteristics (the essential aggregates in economics, or the compensations of the various subjects or participants in micro-economy, from the value of the turnover, to profit, or from salary to interest rate, etc.), to know and be able to quantitatively describe the relationships between the variables, their structural, temporal and spatial dynamics, to estimate the parameters of the significant variables through statistical inference, delimiting the impact of a number of economic processes and phenomena where the respective variables are involved factorially or resultatively, to simulate real situations, through scenarios of determined occurrence probabilities, or even to predict, anticipate or foresee changes in the evolution of the interest characteristics. All those elements cannot be conceived without econometric modelling. General economic laws have appeared as mere results of the utilization of econometric models in theoretically knowing the economic facts and systems (the law of demand, the law of supply, laws concerning elasticities and substitutabilities, or adversities on the markets of various products and services, etc.). The situations were not scarce when economic laws considered classical and implacable were contested by the same econometric models, by the tests and decisions implied in their validation through the empirical databases provided by economic reality. To take an example, the econometric estimations have been able to verify, validate, or invalidate certain hypotheses of the economic theory, of the previsions and prognoses, of the magnitude of the real changes.

Taking empirical (*quantitative*) *measures* necessary in the economic theory, and *verifying economic theory in its essence* have systematically extended the object of application of the modern econometric model, away from the domains of classical economics, such as:

- the domain of demand analysis (Friedman M., Haavelmo T., Stone R., Wald H., Schultz M.);
- the domain of the demand-price, or supply-price elasticity (Marshall A., Edgeworth E., etc.);
- the domain of marginal analysis (Jevons W.S., Walras L., etc.);
- the domain of the economic cycle (Juglar C., Kuznets A., Kondratief A., Kitchin W., Hanau A.);
- the domain of macroeconomics, of the business cycle, as well as measuring the results in keeping with SCN (Mitchell C. W., Burns A. F., etc.);
- the domain of the production functions: (Cobb W., Douglas P.H., Arrow K.J., Tintner G., etc.);
- the macroeconomic domain (Goldberger A.S., Klein L.R., Tinbergen J., etc.);
- the microeconomic domain (Griliches Z., Tobin J., Theil H., Fadden D., Heckman J., etc.);
- the domain of data series analysis (Anderson T.W., Hotelling H., Fisher R.A., etc.);
- the domain of crisis analysis and prognosis (Sims, Engle, Muth, Lucas, Sargent, Tobin, Amemiya, etc.);
- the domain of the intervention politicies of the state into the economy (Keynes M., etc.);

up to the specific areas of modern econometrics, i.e. the databases and information, the methodology of modelling, of testing methods, of the temporal approaches, namely towards:

- the domain of information, informational energy, and entropic information (Corrado G., Shannon C., Weaver W., Wiener N., Odobleja Ş., Onicescu O., Geogescu-Roegen N.);

- the pure methodological domains: a) verification of the self-correlation of the perturbation resulting from the application of regression (Hooker, Durbin, Watson); b) evaluation of the belated effect or the time gaps in knowing time evolution, and its model-related application (Brown, Koyck); c) developing the theory of estimation (Haavelmo, Koopmans, Rubin, Zellner, Theil, Reiersol, Sargan); d) elaboration of modely with simultaneous equations (Tinbergen, Klein, Goldberger); e) constructing the macro-economic models based on the Keynesian theory (Wharton, Brookings, Treasurery, LBS); f) improving the analysis and prognosis methods based on spectral analysis (Hannan, Tukey, Granger); g) the statistical prognosis models (Box, Jenkins); h) unification of the econometrics centred on regression. and the analysis of the time series (Econometric Modelling Time Series Analysis), etc.

The modern econometric model centres on the continuation of five great directions of development in the immediate future, and in the medium term: macroeconometrics (whose object is the analysis of the macroeconometric models based on long series of temporal data, where Jan Tinbergen and his modelling became notable, as they centred on the cyclicity of economic evolution; Lawrence Klein, who contributed with models founded on the business cycles, also developing, with Arthur Goldberger, a number of growth models; Alban William Phillips, the author of the famous analysis curve of unemployment and inflation; George Box and Gwilym Jenkins, authors of the Box-Jenkins methodology, which generated a huge corpus of literature of seasonality, and the random variables in economy); microeconometrics (defined through the microeconomic models, where the contributions made by Zvi Griliches, with the supply analysis and modelling are essential; James Tobin with the Tobit model, Henri Theil with the estimation models and the distribution of the income; Daniel McFadden and James Heckman, with the conditioned logical model; theoretical econometrics (which, by means of the theoretical contribution, derived from modelling and analyses, redefined the significance dimensions of econometrics via Trygve Haavelmo's contribution, the author of the probabilistic revolution; and Lars Hansen, the inventor of the generalized method of the moments); financial econometrics (where Robert Engle, Clive Granger, Tim Bollerslev made themselves noted through the conditioned analysis of the dispersion in the finance time series, and the discovery of the peculiarities of those series); non-linear econometrics (especially developed by James Hamilton, through the elaboration of the most intricate filtered econometric model, proposed for the transition situations); Bayesian econometrics (the father of which was actually Arnold Zellner, who reinvigorated Bayesian statistics, and developed the models based on the uncertainty attached to the independent or factorial variables). The process of diversification that econometrics has seen still continues, moving in other directions as well, such as the econometrics of the panel data, the econometrics of qualitative data, territorial econometrics, etc.

On a par with the ever more intense development of the traditional econometric model, the amount of the criticism it received from the users has increased. In accordance with a number of justified critical opinions, the econometric model exhibits essential limitations, beginning with the use of several economic methods that are simplistic in some cases, from the impossibility of the quantitative model of fitting in one or another theory, up to the high margin of prevision and simulation errors, or the absence from the econometric model of explanatory variables connected with the response of the authorities and the economic policies that can sometimes distort, on a short term as well, rationality in economy and economics. The econometric model, in its modern acceptation, presents a continual degradation in time of the first form of the model, a fact recognized through the frequency of the statement "*in business, few (cor)relations preserve, through time, their initial mathematical precision*". The success of the econometric model is not even unanimously accepted among the economists, which are the very people who ought to enjoy its applicability to the greatest extent. Thus, Ludwig von Mises and Friedrich von Hayek, two major representatives of the Austrian school of neo-classical economics, contested formalization, through econometric modelling, of economic behaviour, emphasizing the sad balance of the predictions made on the basis of the econometric models over the last few decades, in spite of the more and more state-of-the-art calculus equipment and the increasingly sophisticated manner of construction, with ever more profound theoretical accents, and virtually lacking the impact of experiment. These contestations have contributed to the multiplication of the economic disciplines, and thus quite recently experimental economics has been added, a branch of economics that consists in conducting laboratory experiments in order to test the various economic micro-models, and thus vying with econometrics in assessing he theories formulated by economics, and even invalidating some of the models formerly validated in econometric terms.

To conclude, when relationships are described as part of the economic processes, the result is the economic model, the very basis of the description of the economic phenomena. In those cases where the theoretical construction is rendered by means of mathematical relations, the mathematical model of the phenomenon analysed is reached. When the model is structured on decisions concerning the testing of a set of statistical hypotheses, the prevalent element is its statistical side. When the model combines all the three characteristics above, it has already become an econometric ne, and its finality is always practical, operational, as it becomes an instrument of monitoring, simulation and prediction of the economic phenomena. The proliferation of the method of econometric modelling over the latter half of the 20th century can only be accounted for through its neutrality, in the sense of being able to allow the study of a phenomena (be it economic, social, demographic, political, ecological) through the agency of methods that are incompatible with its nature, while other methods sometimes prove insufficient in the attempt to explain the phenomenon in question, i.e. to understand its modus operandi from within its own theory or methodology of knowledge.

The physics model and its interstitial derivatives within the body of economics, sociology, demography, and politology

In the option physics has made, the model is a calculation instrument with the help of which one can determine the answer to any question about the physical behaviour of the respective system, or an accurate matrix of a certain segment of the physical reality (two rather common examples could be the model of the inertial reference system, and the atomic model).

At the pragmatic and challenging crossroads of economics (the econometric research) and sociology (or sociological research), or, more recently, even of politology with physics (that is, the thought based on physical, quantum statistic, or the theory of relativity), completely new sciences have been generated over the last three decades, e.g. econophysics and sociophysics, quantum economics, etc., which vie, through their seeming originality and simplicity with the impact of other new modern research methods that emerge and take firmer shape, such as the science of complexity, the science of the neural net systems, of the genetic algorithms, of fuzzy and neutrosophic logic. The historical evolution is an occasion for us to acknowledge the pace of the development of the border disciplines. Hence, the following apt formula: "*Econometrics' models versus physics' models?*"

Contemporary humanistic sciences are nowadays more and more distinctive, from psychology to the cognitive sciences, from sociology to economics, from the political sciences to anthropology, etc. The special humanistic sciences were previously known by the name of moral sciences, and, at the same time, were marked by the tradition of generating analogies with the ideas in the natural world and in the natural sciences. There exists a great diversity of the schools of thought of an economic type: that of the Austrian economists, that of the institutionalists, the Marxist one, that of the social economists, of the behaviouralist economists, of the theorists of chaos, of the Keynesians and post- Keynesians, of the neo-Ricardians, of the Chicago school theorists, of the constitutional political economists, of the supporters of the theory of public choice (the theory of rational choice already represents the focus of the economic discipline, in the balance of the neo-classical microeconomic, and the macroeconomic one).

Physics was born as a fundamental science, in demonstrative or reductive a manner of thinking, only to assume a manner of thinking of a universal type, with Newton. What is a fundamental science? Can there be a unity without fundamentality? The form the unity takes, or should take, especially in physics, is a controversial question, which has led to plurality within the broad community of the whole discipline of physics (v. *Stanford Encyclopedia of Philosophy*). Physics has developed a genuine universe of the activities, between the theoretical and the experimental approaches and trends. That process has led to a lack of unity in the terms of any classical discipline, as well as a greater complexity of the sets of interactions within the usual term of *physics*, as it gradually became a great science, alongside of other disciplines, such as engineering, economics and management. A distinctive feature of the econometric model has to do with the fact that, whereas it shares with the physical model the application of mathematics and statistics, inductively or deductively, descriptively or explanatorily – with respect to the population, and the probabilistic interpretations – it seems that it still lacks the strict and accurate, correct approach to the universal laws in as "recognizable" a manner as in the physical model. The econometric model is a scientific model oriented towards the possibility of choosing, of managing risks, and making decisions with respect to some genuine, often serious problems, but it also involves a number of general aspects that are of special interest in understanding the phenomena or processes. Thus, after two decades of existence, it can be found that:

- the econometric model only refers to certain aspects of the reality, where the man is concerned with limited resources, it is true more often than not in an optimal manner;
- the econometric model always encourages the enforcement of the quantitative and formal methods, it confers intellectual legitimacy, associated with virtues of accuracy and precision, somehow relative, and of objectivity, sometimes only apparent;
- the subjects of the economic aggregates are made of the same simple material, as elements, atoms of the activities, units that are also physical entities: husbandries, households, corporations and financial or non-financial agencies, the labour market and other markets, but the economic laws, as formulated or invalidated through the econometric models, do not have the same type of viability as the models and laws of physics;
- the economic systems modelled in the econometric manner reveal they are on the increase, day after day, in natural or human environments, just like the other types of physical, biological and social systems.

All the above aspects show serious grounds for competition in knowing and quantifying, in modelling and forecasting the real world, simultaneously economic, physical, sociological, etc. The physical model can make a real contribution, through its econophysical, sociophysical, quantum-economic, etc. forms, and in an unexpected manner, to understanding the economic problems, the processes or the decisions of an economic and social nature:

- through its methodology, which can be described as dual: of an analytical and experimental type at once;
- through its solutions of decomposing, coherently and very close to the reality, a system into its constitutive pieces, and its manner of final understanding, known through the formula “the whole is larger than the sum of its parts” (the *Gestalt* phenomenon);
- through its measuring scale, or it quantitative, relevant standpoint, where it describes the qualities of an economic system or its constituent and determinative phenomena, without however omitting the simplicity of the physical universe, assimilable to any other universe;
- through its specific vision and its manner of making references, always in terms of parts of the universe that must be studied within the great structural hierarchy of reality: from a micro-scale to a macro-perspective, which it deals with through its two main extreme disciplines (nuclear physics at the sub-level of the atomic particles, and astrophysics, at the aggregate level of the cosmic and universal type), connecting a great variety of disciplines, from chemistry, molecular biology, organic biology, psychology, up to economics, political sciences and sociology, ecology, geology and climatology and, to end with, astrophysics);
- through its contribution to establishing the equations that simplify, and the methods that describe phenomena with much more accuracy and precision, as compared with any other models, such as production, markets, migration, traffic or transportation, the financial world, etc.

But by far the most important characteristic of the experimental models remains their common origin, given b the laws of conservation, invoked in their writing. A law of conservation, or a law of nature, is a scientific generalization, based on empirical experiments or observations repeated over the years, and which is accepted by the scientific community. The fundamental aim of science is to discover laws. One has to clearly distinguish between the laws of nature and other laws such as the civic, moral, religious, etc. ones. The laws of nature (including those of our human, social, economic and political nature) are conclusions based on controlled scientific experiments, which should be apt to be repeated if their validation must be made. The laws of physics mathematically express the conservation of a quantity, as well as the conservation of symmetries or the homogeneousness of space and time (the object space–time). Hence the major confusion between the mental model as an expression of symmetries wished or hoped for, and the experimental (especially physical) model, as generator of laws of nature, endowed or not with a certain intellectual beauty, a certain aesthetics, also noted in their simplicity and mathematic laconism. The physicists’ interest in the fields of the financial and economic systems has comparatively old roots, and a brief history of the appearance of econophysics can be illuminating in that respect:

Box no.2

In his doctoral thesis titled *The theory of speculation*, defended at the French Academy in Paris, on the 29th March 1900, Louis Bachelier determined the probability for price modifications to occur. Most

probably, that was the actual start of what nowadays is called econophysics. Bachelier's original proposal distributed, normally of in a Gaussian manner, the price modifications, but it was soon superseded by a host of alternative models, out of which the most appreciated was the model based on a movement of a geometric Brownian type, in case the differences between the logarithms of the prices are also distributed normally or in a Gaussian manner. Also, the interest taken by physicists in the fields of the financial and economic systems has relatively old roots, going back to the year 1936, when Majorana wrote a pioneer work, published in 1942 and titled *Il valore delle statistiche leggi nella fisica e nelle scienze sociali*, on the basis of an essential analogy between the laws in statistical physics and the social sciences. Many years later, another physicist, Elliott Montroll, co-authored with Badger W.W., in 1974, the book *Introduction to the quantitative aspects of the social phenomena*. Ever since the 1970s, a series of significant modifications took place in the world of finance, which eventually generated the new scientific domain of econophysics. A key year was 1973, when national currencies started to be traded on the financial markets; it was then the first work was published presenting a rationally formulated option of their prices, and again immediately after the 1990s, when an increase I the number of physicists occurs, who tried to analyze the model of the financial markets, and, in general, that of the economic systems. "Today, the physicists look on the application of statistical mechanics to the social phenomena as a new challenging adventure. It seems that only few recall the manner in which the original process happened, in the days when the science of physics and the social sciences were the germs of mechanistic physics...". the neologization of the term *econophysics* by Rosario Mantegna and H. Eugene Stanley during the second conference of statistical physics in Kolkata, in 1995, constitutes the official birth certificate of that new inter-, multi- and transdisciplinary science. Moreover, physics also had a previous dominant effect in the evolution of the formal economic theory, and yet the historical interdisciplinarity between physics and economics, consecrated through econophysics, seems to be a model for an approach in the future of the multidisciplinary sciences. Rosario Mantegna and H. Eugene Stanley proposed the first definition of econophysics as a multidisciplinary domain or science reuniting "the activities of the physicists who work with questions and problems of economics, in order to test a variety of new conceptual approaches deriving from the physical sciences". Another even more revealing, and more synthetic definition of econophysics considers that it is "an interdisciplinary research in the field of application of the methods of statistical physics to the problems in economy and finance". The current stage of development, but mostly the dynamics of econophysics, are really exceptional. According to some historians of science, mechanical statistics or statistical physics was developed, in the second half of the 19th century, by James Clerk Maxwell, Ludwig Boltzmann and Josiah Willard Gibbs, while others say that the role played by the physical models in setting up the current model of econophysics seems to be older than two centuries, using arguments from the works of N. F. Canard, where, as early as 1801, demand and supply were described in the very terms used for the diametrically opposed forces in classical mechanics, or through the concept of general equilibrium of the economic theory, a concept developed by Léon Walras under the influence of the physicist Louis Poinsot, but especially through the mere fact that *the father of mathematics applied to economics, Irving Fisher, was one of Josiah Willard Gibbs' students, none other than the father of statistical mechanics.* All the experts are unanimous in recognising the primacy of Ettore Majorana in the domain of approaching the economic processes through statistical physics. To begin with, the application of such concepts as that of law of repartition or distribution, correlation, scaling, unpredictability of the time series and of the random processes specific to the financial markets became possible only after the physicists obtained remarkable results in statistical mechanics through the contribution of statistical investigation and of mathematical formalization. The oldest example of fitting a mathematical law or repartition to the apportioning of the wealth, in a stable economy, belongs to an Italian statistician and mathematician, whose name was Vilfredo Pareto. Secondly, the advance of financial mathematics achieved by Louis Bachelier was important: he quantified the probability of appearance of a price modification, and anticipated, in that sense, the researches of Albert Einstein or Norbert Wiener. Three events underline the evolution of econophysics: in 1973, the appearance of the formulas of evaluating the rational option in the case of a price, i.e. the Black & Scholes formula; then, after 1980, the vast amount of electronic data readily and promptly availably, stored on the financial market; and finally, since the year 1990, an ever greater number of physicists have tried to analyse and model the financial markets and, in general, the economic system, new interdisciplinary journals have been published, new conferences have been organized and new domains, areas and potential applicable themes have been identified. The researches of econophysics have dealt with the distributions of profits on the financial market, the time correlation in the series of financial data, the analogies and differences between the dynamics of prices on the financial market and the physical processes, by turbulence, the distribution of the economic stocks and the rise of variation rates, the distribution of the size of the firms and the growth rates, the distribution of the urban dimension, the distribution of scientific discoveries, the presence of a strong correlation in the price changes, motivated by the reconsideration of a number of opinions or views, the distribution of the income and of wealth, the studies on the statistical properties of the growth rates. The statistical properties of the economic performance of such complex organizations as the universities, the regions or even the nations have been steadily investigated by econophysics. A new

characteristic of econophysics, on a medium and long term, will result from the new researches on rural-to-urban migration and on the growth of cities. The real criticism levelled at econophysics issues from the lack of the variable age, since the models of econophysics consider the economic agents as eternal atoms, much in contrast to the evolution of incomes and of wealth as functions explained through age, which are studied in economy on the basis of the so-called physical models of coverage (Paul Anglin). The first models published by physicists in a journal of physics belonged to Mantegna (1991) and Takayasu (1992), although the latter had developed it several years before. Even a Monte Carlo simulation of the market had already been published in 1964 by Stigler, as a representative of the school of economics in Chicago. Economics Nobel prize winner H.M. Markowitz published together with Kim a first economic model similar to the econophysics ones as early as in 1987, after the Wall Street crash. After the year 2000, econophysicists became mature enough to be able to afford to make generalized applications, a domain which was called econo-engineering. Since the official birth of econophysics, Romanian scientific researchers working in that multidisciplinary field have published a lot of major papers. Among these genuine pioneers one must mention Adrian Drăgulescu, Radu Chişleag, Mircea Gligor, Ion Spinulescu, Mircea Bulinski, Carmen Costea, Margareta Ignat, Anca Gheorghiu, etc. Since 2003, when the first book called *Econophysics* was published in Romania by Mircea Gligor and Margareta Ignat, a book followed, in 2007, by the work titled *Investment Econophysics* authored by Anca Gheorghiu and Ion Spinulescu, and in 2009 de *Exploratory Domains of Econophysics. News EDEN I & II*, econophysics is, in Romania too, a discipline with a recognized bibliography, and also an MA discipline in the academic curricula.

Compared to the thought of mathematical statistics and of the classical type of econometrics, the modelling ways of thinking of econophysics and its models have revealed the fact that the heterogeneity of the data observed and processed from the economic reality must be explained through a theoretical approach centred on homogenization. And, in fact, this is the very chief role of the methodical thought of physics, to unify and simplify the current econometric model. The science of finance, of economic investment, or the financial markets, represents only a small portion of the economic theory, yet a part where the statistical data exist in profusion. In econophysics, the research activities centred on the economic phenomena are preceded by the formulation of new concepts taken over from physics into economics, by new methods applied to the range of economics, and especially by the successful utilization of research models transferred from physics in the economic phenomena and processes which exhibit similitudes in keeping with the data provided. Three out of the remarkable econophysical model, which have already become historic, can easily exemplify the above assertions; these are the model of diffusion, the model of the laws of power, and the fractal model, all of which are applicable within the investment economic, financial and banking space. Modern econophysics has developed a new learning and teaching system intended for econophysicists, composed of several methodological parts: a) basic mathematical methods; b) basic econophysical methods, c) methods centred on the theory of chaos, and fractal methods; d) methods specific to the experimental and virtual markets.

The classical examination methods and the concepts concerning each part round up the training of a contemporary econophysicist, a profession which has become, after that of an econometrician, and before that of a sociophysicists, quite important in today's world.

Sociophysics has become an attractive research domain in the last two or three decades, despite the controversies between sociologists and sociophysicists; it is all due to its extraordinary potential to allow the understanding of a simple principle in keeping with which social phenomena will always be victorious, unlike the scientific theories that explain them. By using statistical physics on a large scale, by modelling the relevant social phenomena, such as those of the making up of the cultural, economic or political opinions, the dynamics and dissemination of the opinions, the origin and evolution of language, competition, conflict, the behaviour of the masses, the spreading of the rumours, social contagion, the net systems of the Internet and the World Wide Web, scientific cooperation and research, the appearance and evolution of the terrorist networks, etc., sociophysics tries to supply new solutions in modelling such phenomena as the interconnexion between the dynamics of a number of social or demographic indicators (life expectancy, birth-rates, fertility, etc.), and the distribution of wealth and well-being, religion, the ecosystems, friendship, the social and traffic networks, etc.

Box no. 3

The origins of sociophysics can be detected as belonging to the '70s and '80s. One of the most frequently cited authors is Serge Gala, who published his papers in *Journal of Mathematical Sociology* and in European *Journal of Social Psychology*. The apparently conflictive nature of the new discipline, called

sociophysics, in relation with the scientific communities of the classical physicists, is best described in his book *Sociophysics: A Personal Testimony (2004).* Physicist Elliott Montroll was the co-author of the first book that anticipated the evolution of this new science called sociophysics, alongside W.W. Badger, in 1974; the title of the book was *Introduction to Quantitative Aspects of Social Phenomena.* Sociophysics was defined, by association with econophysics, as the specific phenomenon of using the models of physics in sociology, as the first objective of the new science was to deal, in its modelling, with the human individual as statistical physics and the quantum physics or mechanics treat particles. Physics concentrates up to this day on the scientific and technological aspects of human society, and accepts Alfred Lotka's ideas, concerning the human populations as the owners of genuine solutions of transforming their own energies into specific dynamics (demographic migrations, cultural, educational, religious, behavioural changes). The sociophysical modelling can change the possibilities of the human population to know themselves, and physics itself dynamizes the investigation effort through its traditional analysis models based on quantum thinking, through the method of statistical physics, together with fuzzy logic, through the science of complexity, or through the methods specific to sociology; it thus enriches the methodological supply of sociophysics, the initial name of which was intended to be *psychophysics*. Starting with the 21st century, sociophysics is really a new science, and not only a mere multidisciplinary or transdisciplinary slogan. Among the most important pioneers of the new science, we could mention, in addition to Serge Galam (*Sociophysics: A Personal Testimony*), Dietrich Stauffer (*Sociophysics Simulations I:Language Competition),* Paris Arnopoulos (*Sociophysics: Chaos and Cosmos in Nature and Culture*), etc.

Delimiting the object of study, and the objectives, describing the specific models, debating the part played and the potential of econometrics versus econophysics, sociophysics, quantum economics, and the sciences of complexity in the system of higher education, and in Romanian scientific research, can represent opportunities, and also necessities for the normal evolution of the process of mental and experimental modelling, in order to both optimize the teaching, and the research processes, in an educational, economic, technical and social context. Econometrical thought has remarkable similarities with the econophysics, sociophysics, quantum economics thought, while also having a number of significant differences, which indicates perspectives of genuine competition, no less than possibilities of reuniting them into a multidisciplinary modelling by far superior to mere reality, which must necessarily and naturally include statistical physics, as well as the physics of a quantum or relativistic type, the statistics of a quantum type, sociology, psychology, etc.

A final remark

The inter-, trans- and multidisciplinary model turns to advantage the language and methods of mathematics, the statistical methods of testing and decision-making, econometric iteration, the pattern of thinking the physical system in assessing reality (mechanic, quantic, thermodynamic, acoustic, relativistic, etc.), the sociological behaviour of the elements in the system (the human behaviour in sociology, the behaviour of the economic subjects in the System of National Accountancy, etc.), and the real variables of the segment under research (the cash flow in economy, the human behaviour in sociology, etc.). The inter-, trans- and multidisciplinary model is superior the unidisciplinary one, and the models with a physical support of the econophysical, sociophysical, quantum economic type, and especially the model of the science of complexity become a living proof of those concrete attempts of scientific modelling of great diversity and universality. The conclusions and the impact on the whole of the scientific theory, existing prior to the modelling, bring back into discussion the pragmatic quality of the modelling. One must not forget that the constant aim of econometric or physical modelling, in all its concrete forms, is to identify the suitable model for solving a certain real problem in nature (economy, society, science, etc). Basically, it is not finding models in themselves which is significant in this connection, though that activity certainly has its fundamental importance, and even a certain charm, but finding those models which prove, by confirming of discarding them, theories and experiments, predicting with very small errors, simulating with a major decision-making impact.

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