The Need for Multidisciplinarity in the Academic Research of Modern Universities

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Abstract: *In the present article, the authors start from the experience derived from the first two workshops of econophysics conducted at the University of Piteşti, EDEN I & II, in the period 2008 -2009, identifying and drawing a tentative hierarchy of a number of requirements of modern research, centred on multidisciplinary modelling and the advantages of turning to account multidisciplinary thinking within the framework of today's European academic community. The paper describes multidisciplinary modelling, its typology and role in scientific research, mainly taking support on the results of the two above-mentioned workshops, while illustrating its special impact in the academic milieu, through the contribution of the kind of thinking specific to econophysics, sociophysics, of fuzzy logic and fuzzy sets in the in-depth understanding of the economic and social phenomena; it extends the knowledge of a set of complex sociological aspects, of the populations of economic agents with a high degree of diversity and variability. A number of final remarks are definable as both a set of conclusions, and (especially) an open invitation addressed to all those interested to take part in EDEN III – 2010 (http://www.upit.ro/ccma/EDEN/project_info_EN.htm)*

Key words: *Econophysics, Sociophysics, Fuzzy logic and sets, Multidisciplinary thinking and modelling*

INTRODUCTION

The last three decades have almost doubled the number of the officially recognized sciences, the overwhelming majority of which are interstitial developments in interdisciplinary areas that were not explored up to that point. This is how, for example, econophysics and sociophysics appeared at the intersection of physics with economics and sociology, and, similarly, within the interval between 0 and 1, a teeny, negligible, apparently non-existent interval in the discreet approach – that of the binary answer, fuzzy logic and fuzzy sets evolved, consequently continuously re-sizing the space of academic research in the modern university. Another element of considerable impact in the modern academia, in keeping with which "the sum total of the parts is always larger than the whole", was represented by the systemic approach, which formulated the laws by means of which is decoded what is currently called a „complex system", a system that exhibits a number of global, emergent properties, which cannot be reduced to the summation of their individual properties, and where the multi-variable and non-linear character of the mechanism involved, on the one hand, and the interaction between the component parts of the system, on the other hand, become the essential aspects that permanently broaden the gap between the contemporary type of research and the classical type. The macroscopic complexity of the phenomena under research, as well as that of the populations, or the public investigated, have become not only a direct consequence of the microscopic dynamics, but also a result of self-organization, of the inter-connexion, and the feedback exerted by the particles that are in a state of perpetual interaction (be they economic actors, individuals, household, etc.). Another significant element of modern academic scientific research is represented by multidisciplinary thinking and modelling, which combine and multiply, as against uni-dimensional thinking, which isolates. These three aspects constitute the gist of the main conclusions drawn by, and detailed through scientific papers and dialogues within, the workshop titled "Exploratory Domains of Econophysics. News (EDEN) I & II, conducted over the lapse of two consecutive years, 2008 and 2009, at the University of Piteşti (http://www.upit.ro/ccma/EDEN/project_info), and are actually the very essence of the present paper.

MULTI-DISCIPLINARY THINKING AND MODELLING

Logic was probably, in its capacity as a mode of thinking about thinking, the first scientific discipline achieving unanimous recognition. Mathematics has come, as a result of the studies on quantities and hierarchies, turned into theorems by means of logical derivation, to be called a science of quasi-general usefulness, yet, without physics and its necessary limits and aspect of finiteness, introduced into mathematical reasoning, the results of scientific knowledge would rather be axiomatic systems of infiniteness. Through methodically measuring the manner in which the characteristics of populations vary statistics rounds up logics, mathematics and physics, while emphasizing the importance of observation and reasoning, in much the same way as physics does, by means of experiment and simulation, in its perpetual attempt to grasp reality. It is computer science and information technology that allowed processing an enormous amount of information, which in turn allowed formulate laws, rules and predictions of a much higher degree of accuracy and precision. And so, the broad spectrum of natural science is reached, where science describes a systematic study, or the knowledge acquired subsequent to that study conducted on nature, starting from human nature (anatomy, sociology, etc.), up to animal, and even inanimate, nature (biology, geology, etc.). Science emerges when at least three elements are joined together: a distinctive theory, a segment of reality as a specific object, and a model interposed between theoretical investigation and its object of study. Sciences have their own characteristic models and laws, acquired mainly thanks to their inclination for measuring their object of study. Even the exclusive answer to the question "what are a model and the modelling itself" constitutes a difficult undertaking, and needs different approaches as in the illustrative variants:

- in the perspective of mathematics, the model and modelling itself are superposed to a certain type of measuring methods, specific to mathematical research, with a view to explain, in an objective manner, the manner in which the micro-components and their mutual interactions, either interpreted individually, or grouped in subsystems, generate and explain the whole of the system to informational energy or a definition and non-contradictory description of a number of processes and phenomena, of theses, postulates and axioms, as well as their logical-mathematical correspondence;
- in the optima of physics, a model is a calculating instrument, with the help of which one can determine the answer to any question concerning the physical behaviour of the system in question, or else a precise pattern of a certain segment of the physical reality (two examples, which are today as well-known as to become banal, are the modelling of the inertial reference system, and the atomic model);
- the statistical- or physical-mathematical type of modelling is a mathematical transcription of a number of simplified hypotheses about the state or evolution of a social-economic phenomenon, or physical system under the factorial influence of variables that are physical or can be assimilated to the physical ones;
- within the structure of the model, the causes equalize the effects as a logical context;
- in keeping with modern sciences, the multi-disciplinary modelling becomes the optimum instrument for solving a number of complex general problems, and modelling turns into a series of means meant to disclose the real nature of the problems, where the isolated vision does not allow one to formulate characteristic laws.

The multi-disciplinary modelling turns to account the language and methods of mathematics, testing and statistical decision, the pattern of physics in assessing reality (quantum, thermodynamic, acoustic, etc.), as well as the real variables of the segment subject to research (money flow in the economy, human behaviour in sociology, etc.), using information technology and computer science. How can one manage to practically construct a model? The starting point is direct experience, or unmediated contact with reality. In order that a theory could be turned an experiment, or into an "organized contact with reality", a theory is formulated, which is subsequently represented by a material, intuitive or symbolic model, as a filtered reflection of reality. But it also needs "the dogmatics of isolation". In order to illustrate a phenomenon, the theory isolates it from the contingent, very much as the experiment is underlain by a type of material (i.e. laboratory) isolation. Studying a phenomenon in isolation also presupposes defining the framework of the isolation through postulates or axioms as "something that goes without saying". Modelling, as a complex iterative process, oscillates between simplified variants like the "triad" (formulating a hypothesis, collecting the experimental material, and verifying the hypothesis), and excessively detailed variants (formulation of the initial model followed by the forming of repartition classes, gathering the experimental material or the data, choosing a particular repartition, checking the degree of concordance of the repartition chosen with the real situation and formulating the hypotheses that explain the random mechanisms that have generated the data). The typological diversity of the models results from the great number of the scientific theories that they reproduce. Seen from the angle of the aim they were created for, the models fall in two major types: the category of the rational or theoretical models, and the category of the operational models, or prediction (decision-making) models.

EDEN I & II led us to the idea that modelling can be uni-disciplinary, but it will remain isolated in the past, as well as modern, i.e. covering reality, and, implicitly, multi-disciplinary. For a succinct description of multi-disciplinary modelling, a few clarifications are relating to the following concrete stages:

1. the structural defining of the system (isolating the phenomenon, formulating the questions, identifying the major interest variables),
2. the preliminary formulation (sets of hypotheses and conclusions concerning the relationships between the variables), collecting the empirical (relevant) data,
3. the estimation of the parameters and of the functional forms,
4. the preliminary (gross) testing,
5. the additional testing (based on the new data),
6. the decision – accepting or rejecting (in conditions of predictions conforming or failing to conform to the available empirical evidence).

The architecture of multi-disciplinary modelling capitalizes on:

a) minimal simplification through hypotheses, or the existence of a minimal number of propositions not connected mutually, and undemonstrated propositions (out of two interpretations of a phenomenon, the interpretation having fewer suppositions or simplifying hypotheses is preferred);
b) he simple alternative (the highly intricate models failed to lead to categorically better results, as against the simple extrapolation formulas.);
c) the value certified through the dialectical reasoning (a model facilitates the discussion, clarifies he results and limits the reasoning errors);
d) the cultural component (if the humans' economic and social actions were independent of their cultural inclinations, the enormous variability of the economic and social configuration in point of time and place could by no means be accounted for);
e) shifting from one- to multi-disciplinarity, through successive models (improvement through imitation, through analogy, and through passing from one type to another).

Synthetically, the relationship between completeness and precision/accuracy generates specific models:

Degree of the data's completeness and precision generating the model's typology

Table no.1

Degree of completeness of the data	Degree of precision of the data	Typology of the model
Maximum	Maximum	Deterministic
Relatively low	Relatively high	Probabilistic
Relatively high	Relatively low	Fuzzy
Relatively low	Relatively low	Intuitive
Minimum	Minimum	Non-deterministic

The algorithm of the model has three characteristic features: determinism in point of performance, succession in point of operation, universality in so far as the spatial, temporal and structural entries and limitations are concerned.

SOME ECONOPHYSICS' AND SOCIOPHYSICS' MODELS PRESENTED TO EDEN I&II

Econophysics is an interdisciplinary research field applying methods of statistical Physics to problems in Economics and Finance. The contemporary way to define

Econophysics is to do so in terms of the ideas that it involves in effect physicists doing Economics with theories from Physics, this raises the question of how the two disciplines relate to each other and it explains interest rates and fluctuations of stock market prices, these theories draw analogies to earthquakes, turbulence, sand piles, fractals, radioactivity, energy states in nuclei, and the composition of elementary particles.

Sociophysics is a new insight followed by transferring and further developing ideas and concepts common to Physics. This very young science means also the applicability of much of elementary statistical physics to the social sciences, insight Biology, and Ecological Systems. First named Psychophysics, Sociophysics can be described as the sum of activities of searching for fundamental laws and principles that characterize human behaviour and result in collective social phenomena. Sociophysics tries to model the dynamics of social and economic indicators of a society and investigate how life extension will influence fertility rates, population growth and the distribution of wealth, religion, friendship and sex, social network, traffic, etc. *Sociophysics* has an attractive and relevant potential used for understanding the social phenomena.

Econophysicists' and Sociophysicists' models seek to integrate the Physics' methods and laws with classical Economics' and Sociology's theory and thinking, seeing this new domain of applied Physics as an unlimited one. Econophysics and Sociophysics replace conventional ways, with the new and broader views of Physics' thinking. In Econophysics, the activities of research focused on economic phenomena but are analyzed by concept, method and model of physics. Here three of most discussed examples to EDEN I &II are:

a) the derivation of a price's distribution in the stock market (the change in the price "*x*" of stock market could be considered a random among dealers, then can derive a diffusion equation as a Brownian motion, for distribution *f(x,t)* of price in the stock market):

$$\frac{\partial f\left(x,t\right)}{\partial t}=\frac{1}{k}\times\frac{\partial^{2} f\left(x,t\right)}{\partial x^{2}} \qquad (1)$$

b) distributions of the form that follows a *power law* as: $\ln p(x) = -\alpha \ln x + C$, where the constant α is called exponent of the power law, and *C* is constant and mostly uninteresting (once α is fixed, it is determined by the requirement of normalisation to 1), or in the case of taking the exponential of both sides, this is equivalent to: $p(x) = Cx^{-\alpha}$ (2)

(a power-law distribution occurs in an extraordinarily diverse range of phenomena such as Finance, Macroeconomics, Demography's urbanism)

c) a fractal and chaos analysis originating as Benoite Mandelbrot pointed out that the change in the price of the stock market has a fractal structure for certain range of time interval and characterized as a self-similar structure expressed as: $x(t) = Ct^{D}$, (3) where *D* is a fractal dimension, calculated by the box counting method. (The fractal structure is special case of a chaos and chaotic behaviour is very common in a non-linear system as for an economic system; whether the process is chaotic or not can be determined by sign of Lyapunov index λ defined as: $\lambda = 1/n \, \Sigma \log | F'(t) |$, and when λ is positive (negative) then the process is chaotic (non-chaotic). Modern Econophysics has developed a new learning system for econophysicists, consisting of some methodological parts like Basic Mathematics, Basic Econometrics, Echonophysics' methods, chaos' and fractals' methods, virtual market, reviewing classical methods and concepts concerning to each part: Mathematical representation and analysis of the data for basic Econometrics.

Sociophysics aims at a Statistical Physics modelling of large scale social phenomena, like culture and opinion formation and dynamics, cultural and behavioural dissemination, the origin and evolution of language, competition and conflicts, crowd behaviour, social contagion, gossip and rumours evolutions, Internet and World Wide Web, cooperation and scientific research, appearances of terrorism etc. A good overview of several fields of application and an accessible, entry-level description of many simulation models can be interpreted as forming part of the Sociophysics. For instance, in a paroxysm crisis of fear, opinions can be activated very quickly among millions of mobilized citizens, ready to act in the same direction, against the same enemy, but a lot of phenomena can be studied within the new emerging field of Sociophysics, in particular the dynamics of minority opinion spreading, the rumour propagation, etc. The opinions of the individuals may change simultaneously (synchronous dynamics as in Glauber theory) in discrete time steps according to the rule:

$$\sigma\, i(t+1) = \begin{cases} \sigma\, i(t) & \text{with the probability } \dfrac{\exp(-I_i/T)}{\exp(-I_i/T)+\exp(I_i/T)} \\ -\sigma\, i(t) & \text{with the probability } \dfrac{\exp(I_i/T)}{\exp(-I_i/T)+\exp(I_i/T)} \end{cases} \tag{4}$$

In this model parameter „T” could be called the “social temperature” and I means the impact that determines the individual person to change his opinion when $I_i > 0$.

The most remarkable pioneers of Sociophysics probably are Serge Galam (*Sociophysics: a personal testimony*), Dietrich Stauffer (*Sociophysics Simulations I:Language Competition),* Paris Arnopoulos (*Sociophysics: Chaos and Cosmos in Nature and Culture*), etc. Finally, there is a major conclusion in Sociophysics, that in modelling the human group’s behaviour, a crucial point always remains to study the group decision making and the related issue of the collective opinion formation and dynamics.

FINAL REMARKS AND FUTURE WORKSHOPS

Econophysics and Sociophysics or even fuzzy models are multi-disciplinarity models and they try to unify, while classical models remains uni-disciplinarity models and they have succeed only to isolate. Thence, the culture of multidisciplinary modelling remains a practical issue for a modern university. The typical models of Econophysics and Sociophysics were and still remain the results of the weak or of the strong signals coming from outside, from the reality, into science’s thinking.

To conclude, we think that an open invitation should necessarily be transmitted to all those interested in the field, to take part in EDEN III – 2010, a new encounter with multidisciplinary types of modelling, so necessary in the scientific research of the modern European academia, belonging to an entrepreneurship-based type, centred on projects, and on a more pragmatic relationship with the labour market.

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