ECONOPHYSICS Section

TWO DECADES OF ECONOPHYSICS-THEORIES, PERSONALITIES. ROMANIAN CONTRIBUTIONS

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Abstract. *At the end of the 20th century, a new interdisciplinary science, called Econophysics has emerged. This new discipline applies theories and methods, previously formulated by physicists (such as statistical mechanics, power laws, stochastic processes and nonlinear dynamics), in order to solve problems in economics and markets. Physics theories and models that have been applied in economics until now include the kinetic theory of gas, chaos theory, statistical mechanics, fluid dynamics, diffusion theory, classical mechanics, quantum mechanics, stochastic processes, cellular automata, nonlinear dynamics, neural networks, pattern recognition, theory of turbulence, random matrix theory, string theory etc. Some of the most prominent personalities in the field of Econophysics are: H. E. Stanley, V. Yakovenko, J-P. Bouchaud, Bikas K Chakrabarti, T. di Matteo, E. Scalas, E. Guevara, M. Ausloos, J. Mimkes, F. Kusmartsev, I. Spânulescu and Anca Gheorghiu. Definitely, the list is not complete, there are many other scientists that worth a mention in a future monograph of Econophysics. The paper enumerates also some notable achievements of econophysicists in Romania.*

Econophysics tries to clarify empirical facts that are not explained by today's conventional financial economics. Still, there is a deficit of communication between physicists and economists, consequently mainstream economists to do not approve or are unenthusiastic to accept furthermost of the theories of Econophysics, partly because of their preconceived ideas, their theoretical background, and partly due to the difficulty/impossibility in testing such models. Their reduced knowledge in natural science prevents them to explain the tangible economic problems more exactly and proficiently. Physicists, at their turn, often simplify economic and social reality so much, that economists cannot accept their theories; still, physicists come with no preconceptions and often, with a lot of enthusiasm and original viewpoints. The conclusion of this paper is that, in the future years, economists and physicists have to overcome their current lack of communication, since Econophysics is a developing science that will, most certain, provide new theories and models in the future years.

Keywords: *Econophysics, Complexity, Interdisciplinary, ENEC.*

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1. The evolvement of Econophysics as a new science

In the last three centuries, Physics and Economy have influenced each other; famous authors introduced in their works on economy some notions from exact sciences-Daniel Bernoulli, Pierre Laplace, Adolphe Quetelet. Economics is a science that has been greatly influenced by people with solid physics and mathematics knowledge, at the middle of the 19th century. While implementing different projects, the members of the French corps of state civil engineers, led by Dupuit, solved different economic problems with the help of mathematical tools [1]. Likewise, economists as well have influenced Physics-Vilfredo Pareto, Levy and Mandelbrot, L. Bachelier.

Physics has played a key role in the development of economic theories in the 19th century, since some of the founders of neoclassical economic theory were originally trained as physicists. Josiah Willard Gibbs, one of the fathers of Statistical Mechanics has had greatly influenced his student Irving Fisher, who, in 1892, translated some important equations of physics into the economic language and who issued the Statistical Theory of Index Numbers. The same Gibbs has had influenced also Paul Samuelson, who published in 1947 his famous „Foundation of Economic Analysis, with a solid mathematical argumentation [2]. The research of economic processes with the help of mathematics or physics started as early as the first decades of the 20th century, through statistics and econometrics. Physicists have developed new study methods and models for economic phenomena or processes.

In the 20th century, several crises have shattered the trust on investors in the markets and in the ability of economists to predict terrible disasters such as: the financial crisis in 1929-1933, the Oil shocks (1973/1974), Black Monday Crash in 1987. The next century also started with the sub-prime crisis of 2007-2008 that triggered a truly global economic crisis in the following years. All these events needed explanations, since for many decades, economic methods dealt with homogeneous agents, linearity and equilibrium, while the reality was that markets fundamentally depended on heterogeneous agents and far-from-equilibrium (in fact with chaotic) situations.

Some innovative trading methods have definitely changed the world of finances at the end of 20th century. In 1973, currencies began to be traded in financial markets and their values were determined by the foreign exchange market, active 24 hours a day. In the 1980s, financial markets began to enable the electronic trading of big amounts of money, assets, stocks, and goods throughout the world.

Financial economics was born in the 1960s and thirty years later, a new field of research called „Econophysics was created, aiming at reinventing financial theories. The fantastic advance of the computers and Internet technologies made available large amounts of financial data; furthermore, under the pressure of the phenomenon of globalization, new methods of research were needed in economics. Physicists were achieving better simulations of stock-price variations in comparison with economists. No wonder that people holding a doctorate in Physics were welcomed in high-skilled quantitative analyst positions of international banks or companies listed on the most important financial markets (New York, London, Tokyo, Paris etc). Leaders of such companies or banks understood that they have to let behind classical economics and develop new tools, as attempted by behavioral economists and econophysicists.

Under such circumstances, a new interdisciplinary/border science, called „Econophysics has emerged. This new discipline applies theories and methods, formerly formulated by physicists (such as statistical mechanics, power laws, stochastic processes and nonlinear dynamics), in order to solve problems in economics and markets.

The term „Econophysics was coined by Harry Eugene Stanley, to label the papers written by physicists in the problems of stock markets, in a conference on statistical physics in Calcutta in 1995 and first appeared in its proceedings publication in Physica in 1996. Later, the Romanian socioeconomic physicists Gheorghe Săvoiu and Ion Siman concluded that „Econophysics was from the beginning the application of the principles of physics to the study of financial markets, under the hypothesis that economic world behaves like a collection of electrons or a group of water molecules that interact with each other, and the econophysicists are always considered that, with new tools of statistical physics, and the recent breakthroughs in understanding chaotic systems, they are making a controversial start at tearing up some perplexing economics and reducing them to a few elegant general principles with the help of some serious mathematics borrowed from the study of disordered materials [3].

Victor Yakovenko and his collaborators have explained that „Econophysics does not literally apply laws of physics, such as Newton's laws or quantum mechanics, to humans. It uses mathematical methods developed in statistic physics to study statistical properties of complex economic systems consisting of a large number of humans [4].

Some researchers have even coined different terms deriving from the science of Econophysics. For instance, the German physicist Jurgen Mimkes, Professor at the University of Paderborn, originated the term of

„Econo-thermodynamics. His explanation for clarifying this term is very interesting: „Physicists oftenmodel economic interactions like collisions of atoms in gases: by interaction one agent gains, the other loses. This leads to a Boltzmann distribution of capital, which has been observed in wealth distributions of different countries. However, economists object: no economic agent will attend a market in which he gets robbed! This conflict may be resolved by writing basic laws of economics into terms of calculus. In these terms the daily struggle for survival of all economic systems turns out to be a Carnot cycle that is driven by energy: heat pumps and economic production depend on oil, GNP and oil consumption run parallel for all countries. Motors and markets are based on the same laws of calculus (macroeconomics) and statistics (microeconomics). Economic interactions mean exploiting a third party (nature) and are indeed close to robbing! A baker sells bread to his customers, but the flour comes from nature. Banks sells loans to investors, but the money comes from savers. Econo-thermodynamics is a thrilling new interdisciplinary field [5].

The first conference dedicated to Econophysics was organized in 1997 by the Physics department of the University of Budapest. In 2012, for the first time, the term of „Econophysics was found of 1000 times in Google Scholar, meaning that the frequency of using this term has exponentially grown in the latest two decades. More and more scientists become aware of this emerging science. The modern theoretical tools of Econophysics are at the forefront of interdisciplinary research and the investigation of complex economic systems.

Similarly, with traditional Physics, Econophysics can be divided into two branches: experimental and theoretical, the first having as purpose the examination of data series from the financial markets, the second creating models to match empirically determined values.

Physics theories and models that have been applied in economics until now include the kinetic theory of gas, chaos theory, statistical mechanics, fluid dynamics, diffusion theory, classical mechanics, quantum mechanics, stochastic processes, cellular automata, nonlinear dynamics, neural networks, pattern recognition, theory of turbulence, random matrix theory, string theory etc.

Ion Spânulescu and Anca Gheorghiu, from Hyperion University (Bucharest, Romania) have observed that all sub-domains that used statistical mathematics and statistical physics methods could be grouped in the major domain of statistical Econophysics, whilst Econophysics sub-domains and models that used models inspired by phenomena and laws from other domains of physics (other than statistical physics) or from other

sciences could be grouped in the major domain of phenomenological Econophysics. „In most models of statistical econophysics is presented the static situation of laws or state of the economic processes or phenomena, found in the form of the normal distribution laws of Gauss type, exponential, logarithmic, or power distribution law, Boltzmann-Gibbs, Fermi-Dirac or Bose-Einstein distributions etc., especially for the study of stock-markets, of wealth or income distribution, of resources distribution (money, gold, oil etc.) of the different categories of products etc. The phenomenological Econophysics models were developed based on analogies between economic processes and laws, and phenomena and laws from fundamental or applied physics (electronics) especially of Electricity, Condensed Matter, Thermodynamics or Engineering (econo-engineering models) [6].

Econophysics explains empirical facts that are not explained by today's mainstream financial economics. However, there is a deficiency of communication between physicists and economists, so mainstream economists to do not agree or are reluctant to accept most of the theories of Econophysics, partly because they are not prepared as mindset or as theoretical background, partly because they are too strongly attached to the „dogmas of the classical economic theories and partly due to the difficulty in testing such models. Their poor knowledge in natural science prevents them to confront the tangible economic problems more precisely and proficiently. Nevertheless, a growing number of economists started to understand the need to applying theories or methods originating from physics to understand or explain economic models.

Still, physicists have to give up simplifying the reality and trying to find universal regularities in economics in the same way like in the science they master-Physics. Sometimes, Econophysics consider companies as everlasting, like atoms, regardless of the evolution of their income, turnover, shareholders and markets. Utility, perfect rationality, perfect competition (notions widely used by physicists) are axioms of little credit among realistic economists. Econophysicists start their studies from the assumption that the companies or consumers behave like a cluster of electrons or a crowd of molecules that interact with each other, and that, with some tools of Physics, they can condensethe ways economic actors behave to some simple, indisputable general principles. But Economics is a social science and the unpredictable human behavior plays a key role in describing some laws applicable in economy.

A Polish researcher, A. Jakimowicz, from the Institute of Economics, Polish Academy of Sciences, in Warsaw, suggests a new term for the

methodological foundation used in multiple fields of research – the „transdisciplinary matrix, derived from the modern general system theory, based on four components: cybernetics, catastrophe theory, deterministic chaos and sciences of complexity. Jakimowicz observes that economists usually build their models on the basis of empirically unverified assumptions, which usually are treated like religious dogmas, whereas Econophysics is an inductive science, based on observations, not attempting to adjust observations to a priori models [7].

Bertrand Roehner considers that the agenda for the next decades should include: measuring social interactions, finding user friendly databases, taking into account the role of big players and testing the models [8].

We should observe that, despite a constellation of scientific models and public available financial data, econophysicists and economists were not able to predict the subprime crisis of 2008, with one notable exception – Nouriel Rubini, Professor of Economics at New York University's Stern School of Business.

2. Forums of Econophysics and prominent personalities

There are very few universities that provide formal courses on Econophysics, most of them are located in Europe; among them, one can mention the „Econophysics course, offered by the Physics Department of the Leiden University – Nederland, Lecturer Dr. Garlaschelli. Starting with 2010, Universitatea De Vest, Timişoara (Romania) has offered interdisciplinary Master degree courses on Applied Econophysics. From September 2014, the prestigious King's College-U.K. has awarded the first position of Full Professor in Econophysics to Professor Tizziana di Matteo. Other universities that offer now courses in Econophysics are those located in: Fribourg (Switzerland), Münster (Germany), Ulm (Sweden), and Dublin (Ireland). On other continents, one can mention the fact that the University of Houston (Texas, USA) incepted the first doctoral program in Econophysics in 2006, followed in 2009 by the University of Melbourne (Australia).

In the latest years, several conferences on Econophysics took place, such as: ENEC, organized by Hyperion University, in Romania (annually, since 2008), Asia-Pacific Econophysics Conference, every year, since 2011, or the Workshop on Econophysics & Sociophysics, 2015, Calcutta, India, Econophysics and Econometry organized by the National Research University High School of Economics in Nizhny Novgorod, Russia, 2015, the conference on Econophysics organized by Tokyo University, 2016 etc.

In 1998, **Yi-Cheng Zhang,** from the Institute de Physique Theorique, Fribourg, Suisse, started the Forum of Econophysics on the website *http://www3.unifr.ch/Econophysics*. The sections of this forums are: Editorial/News/Events/Job openings/Papers/Blogs/Book reviews. Researchers interested in such an interesting subject can join the forum, comment, post articles, books, announce conferences details, offer and find jobs, etc. Other Econophysics Academic Programs and Groups are: Econophysics Research in Victor Yakovenko's group at the University of Maryland and the Academic Program on Econophysics at the University of Houston.

The interest for the Econophysics is revealed by the number of people that are members of the groups focused on this science on one of the most important social networks: almost 800 members on LinkedIn. Even the description of this group is eloquent – the Econophysics group on LinkedIn claim to be a group of researchers, practitioners and other people interested in the growing field of Econophysics and its application to economy and finance. Even though many people consider that social networks are not real forums for science, I consider that they are a real virtual meeting place, a real agora for people interested in this border science, since, usually, they live in different countries, sometimes very faraway geographically, they have different academic backgrounds and, surely, different reasons for joining such a network of scientists.

Some of the most prominent personalities in the field of Econophysics are: H. E. Stanley, V. Yakovenko, J-P. Bouchaud, Bikas K Chakrabarti, T. di Matteo, E. Scalas, E. Guevara, M. Ausloos, J. Mimkes, I. Spânulescu and Anca Gheorghiu. Definitely, the list is not complete, there are many other scientists that worth a mention in a future monograph of Econophysics.

Harry Eugene Stanley (b. 1941, Oklahoma city) is an American physicist and University Professor at Boston University, a specialist in statistical physics, who, for the first time in history, coined the term „Econophysics. In 2000, he published a book, having as a co-author Rosario Nunzio Mantegna – An Introduction to Econophysics: Correlations and Complexity in Finance [9].

In this volume, the authors approach very important fields of the Finance science, by using tools and concepts that are familiar for statisticians and physicists. The chapters of this anthological book are the following: Efficient market hypothesis, Random walk, Levy stochastic processes and limit theorems, Scales in financial data, Stationarity and time correlation, Time correlation in financial time series, Stochastic models of price dynamics, Time correlation in financial time series, Stochastic

models of price dynamics, Scaling and its breakdown, ARCH and GARCH processes, Financial markets and turbulence, Correlation and anticorrelation between stocks, Taxonomy of a stock portfolio, Options in idealized/real markets.

Victor Yakovenko (b. 1961, Donetsk, Ukraine) is the head of the Department of Physics-University of Maryland, a specialist in Condensed Matter Theory and considered one of the founding fathers of Econophysics domain. He published many books and articles on Econophysics. He suggests statistical models for money, wealth, and income distributions; by analogy with the Boltzmann-Gibbs distribution of energy in physics. According to his studies, data analysis of the empirical distributions of wealth and income reveals a two-class distribution: the majority of the population (97-99%) belongs to the lower class, characterized by the exponential (thermal) distribution, whereas a small fraction of the population (1-3%) in the upper class is characterized by the power-law (superthermal) distribution. The lower part is very stable, stationary in time, whereas the upper part is highly dynamical and out of equilibrium. In cooperation with A. F. Cottrell, P. Cockshott, G. J. Michaelson, I. P. Wright, he published a must read book- Classical Econophysics, a monograph that examines the domain of classical political economy using the methodologies developed in recent years both by the new discipline of Econophysics and by computing science. It re-examines the classical subdivisions of political economy: production, exchange, distribution and finance [10].

Jean-Philippe Bouchaud (b. 1962, Paris) co-founded the company Science et Finance in 1994, which later merged with Capital Fund Management (CFM) in 2000 and he became a Chairman of it. Interested in the statistics of price formation, stock market fluctuations and the modelling of financial risks, he had criticized the efficient-market hypothesis and the use of the Black-Scholes model which underrate the risk in options trading, with ruinous consequences for investors [11].

Bikas K Chakrabarti (b. 1952, Calcutta) is an Indian Professor of Physics at Saha Institute of Nuclear Physics, Kolkata and the editor of book series: Physics of Society: Econophysics & Sociophysics of Cambridge University Press. Some of the most important books issued were: Econophysics: An Introduction, Wiley-VCH, Berlin (2011) and Econophysics of Income & Wealth Distributions, Cambridge University Press, Cambridge (2013) [12].

In an article published in 2000, he observes that „analogous to statistical systems in equilibrium, money and the average money per

economic agent are equivalent to energy and temperature, respectively. When the agents do not save, the equilibrium money distribution becomes the usual Gibb's distribution characteristic of non-interacting agents [13].

Tizziana di Matteo works nowadays in the department of Mathematics at King's College London in Econophysics, complex networks and Data science. She has authored over 80 papers and gave invited and keynote talks at major international conferences in the US, across Europe and Asia, making her one of the world's leaders in this field. Di Matteo uses scaling analysis to investigate the characteristics of financial markets, on the basis of daily Foreign Exchange rates, Stock Market indices and fixed income instruments by using the generalized Hurst approach [14].

Enrico Scalas, Professor of Statistics and Probability, University of Sussex, UK and his co-authors, Rudolf Gorenflo, Francesco Mainardi. Presented a general phenomenological theory of tick-by-tick dynamics in financial markets that takes into account the non-Markovian and non-local character of financial time series. They have proposed a general scaling form, based on the solution of the fractional diffusion equation [15].

According to Google scholar (citations), label „Econophysics, the most cited researchers in 2017 are the following:

– H. Eugene Stanley, Professor of Physics, Boston University, cited 150633 times;

– Andrey Leonidov, PN Lebedev Physical Institute, cited 60535 times;

– Eshel Ben-Jacob, Professor of Physics, Tel Aviv University, cited 24117 times [16].

3. Econophysics in Romania

As thoroughly presented in the article 150 years of Romanian research, published in Hyperion International Journal of Econophysics & New Economy, in the 20th century, Romania has had some memorable contributions to the advance of the global science, although there are few persons who are truly aware of the great value of science accomplishments generated by Romanians [17].

Costin Kirițescu was an esteemed economist, who wrote works about inflation, currency, monetary problems in the 40's of the 20th century. Anghel Rugină was an American economist of Romanian origin, honorary member of the Romanian Academy (1990). He wrote many studies, like: Principia Oeconomica: New and Old Foundations of Economic Analysis

(1986); Principia Metodologica: A Bridge from Economics to all other Natural Sciences, Toward a Methodological Unification of all Sciences (1989).

In Physics, in the 20th century, many Romanian physicists became internationally recognized for their discoveries. For instance, the team led by H. Hulubei was involved in an important research project in the field of radioactive isotopes. Alexandru Proca issued the first meson theory of nuclear forces and the equations of the vectorial mesonic field, Ştefan Procopiu is recognized for the first theory of the magnetic moment of the electron (the Bohr-Procopiu magneton), while Ionel Solomon is famous for the nuclear magnetic resonance theory in solids.

Nicholae Georgescu-Roegen (1906-1994) was a mathematician and American economist of Romanian origin, the father of bio theory, a theory that presents an innovative way to see the economy. He observed that the second law of thermodynamics, expressing the entropy principle, is the most economic of all laws of physics. In his ground-breaking book published in 1971 The Entropy Law and the Economic Process, Georgescu-Roegen pointed out the contradiction between the second principle of thermodynamics and the law of entropy – that is, between the unavoidable degradation of natural resources used by mankind as a result of their use and unlimited material growth [18]. In the preface of the Romanian edition of the same book, Georgescu-Roegen makes a confession-that his ideas were formed in his early years, in Romania, when he saw the natural resources, bread and oil, being exhausted; the book is a synthesis in which the economic process appears as a continuation of the biologic evolution, in fact a transcendental extension of this evolution [19].

Anca Gheorghiu (b. 1960, Bucharest, Romania) is the first researcher who defended a PhD thesis on Econophysics at the most famous university of economics in Romania-Academia de Studii Economice of Bucharest (in 2007). She is one of the very rare econophysicists that holds two PhDs-one in Economics, and one in Physics and who is not only a theoretician, because she has applied in practice both sciences in her career. Anca Gheorghiu defended a thesis in Condensed State Physics, in 1998, at the Physics Faculty of Bucharest University. She has published two books on Econophysics, in Romanian language and several articles in English. She is a full Professor of Hyperion University in Bucharest. She wrote many articles, such as: An Econophysics model for the migration phenomena, Economic Amplifier Macrostate Parameter, An Econophysics Approach for the Risk Analysis of the Stock Exchange,

„An Econophysics approach and model for the Keynes's multiplier of investments.

She has proposed, among others, a new Econophysics model, named Economic amplifier, on the electronic amplification principle from applied physics, based on transistor-effect from Physics; such a model can be used for modeling different economic structures or processes such as production or investment fields, steady capital, founds or financial – banking fields, stocks etc. Anca Gheorghiu is also the creator of the Macrostate Parameter, used for the Risk Analysis of the Stock Exchange Market Transactions [20] [21].

Gheorghe Săvoiu is a professor PhD habil. statistician, teacher of statistics and econometrics to University of Pitesti, Romania. He had published several articles and books on Econophysics; the most important is Econophysics: Background and Applications in Economics, Finance, and Sociophysics (Elsevier, London, 2012) [22].

Prof.Savoiu has made in one of his articles (Some Relevant Econophysics' Moments of History, Definitions, Methods, Models and New Trends) a synthesis of the new domains of Econophysics, as they emerge from studies published by the founding fathers of this interdisciplinary science:

1. A thermodynamic formulation of Economics (J. Mimkes);
2. Understanding and managing the future evolution of a competitive multi-agent population (D. M. D. Smith, N. F. Johnson);
3. Empirical studies and models of income distributions in society (P. Richmond & others);
4. The contribution of money transfer models to Economics (Y. Wang, N. Xi, N. Ding);
5. Econophysics of stock and foreign currency exchange markets (M. Ausloos);
6. Econophysics of precious stones (Watanabe, N. Uchida, N. Kikuchi);
7. Quantum Econophysics (E. Guevara);
8. Statistical mechanics of money (A. A. Dragulescu and V. M. Yakovenko);
9. The Production Function (G. Fioretti);
10. Basel II for Physicists: A Discussion Paper (E. Scalas).

Adrian Drăgulescu (b. 1974) is a Romanian-born American who defended his PhD on Applications of Physics to Economics and Finance: Money, Income, Wealth, and the Stock Market under Victor Yakovenko, at

the University of Maryland, on problems of economics and finance analysed using quantitative methods from physics. In 2000, Drăgulescu and Yakovenko published a widely-cited article Statistical Mechanics of Money, in which they argue that: in a closed economic system money is conserved, that money is a type of energy and that each economic agent has a certain amount of average money (or energy). He also asserts that an effective temperature of the economic system can be obtained from this model that will follow the exponential Boltzmann-Gibbs law [23].

Margareta Ignat (c. 1941-) is a Romanian physicist associated with Alexandru Ioan Cuza University (Iasi). She is a specialist in Magneto-hydrodynamics, Thermodynamics and Statistical Physics. In 2001, Ignat published the article „Econophysics: a New Field for Statistical Physics, co-authored with Mircea Gligor [24]. She supervised Gligor's PhD thesis Thermodynamics and Statistical Models for Dissipative Socio-Economic Systems (2003).

Ion Spânulescu (b. 1934-Poroina Mare, Romania) is a very respected academic, with two PhDs: one in Physics at the Energy Institute of Moscow, Russia and one in Electronics at the Imperial Sciences University of Tokyo (Japan), author of 25 books and over 200 scientific articles on semiconductors, thin layers Physics, solar cells, microelectronics. He is a Member of different international scientific organizations, such as: the Electrochemical Society (USA), the Japan Society for Applied Physics, the IEEE Computer Society [25].

Prof. Ion Spânulescu founded in 1990 the first private university in Romania, Hyperion University, located in Bucharest, having several faculties, in different domains, including economics and physics. In fact, it is the only private university with a very large spectrum of sciences and arts being taught, a true Academe for intellectuals, for researchers, for students, even for Alumni, who find in their Alma Mater a creative space for new ideas, projects, and plans. After almost three decades, the university is proud to see many of its former students occupying prestigious places in the society.

Faithful to his life credo-the Science, in his quality of the Rector of Hyperion University, Professor Spânulescu is the enthusiastic promoter of the conference ENEC (Econophysics, New Economy and Complexity International Conferences). It started in 2008 and took place every year in Bucharest, without any interruption. In this way, Hyperion University can be considered as a true pioneer of Econophysics. Most papers presented in the conference were published in the proceedings available in HIJENE

journal (Hyperion International Journal of Econophysics &New Economy). Throughout a decade, ENEC conference has been a cradle of interesting theories, ideas for researchers coming from different countries-Austria, Finland, France, India, Iran, Moldova, Portugal, Romania, Russia, Serbia, U.K., Ukraine etc.

Some important academics have published in HIJENE journal several remarkable papers on Econophysics and complexity: A. Gheorghiu, I. Spânulescu, F. Kusmartsev, S. Galam, M. Estola, A. Le Méhauté, I. Dmitrieva.

Anca Gheorghiu and Ion Spânulescu published An Econophysics model for the migration phenomena, Economic Amplifier Macrostate Parameter, An Econophysics Approach for the Risk Analysis of the Stock Exchange, A classification of Econophysics Direction, „An Econophysics approach and model for the Keynes's multiplier of investments, An Econophysics Model for Investments using the Law of the Electric Field Flow (Gauss' Law).

In the paper „An Econophysics approach and model for the Keynes's multiplier of investments, it is shown the similarity between investments multiplier introduced by J. M. Keynes and the economic development factor introduced by the Econophysics model named Electronic Amplifier, created based on the resemblance between the amplification phenomenon of electronic physics and the economic amplification process based on investments in various economic sectors and units [26].

Feodor Kusmartsev (b. Karakai, former USSR, 1956) is a Professor of Condensed Matter Theory, IOP and APS Fellow-Loughborough University (U.K.). After hisPhD from the Landau Institute for Theoretical Physics (Moscow) in 1983, he worked for Landau Institute for Theoretical Physics, was a Visiting Professor at Tokyo University and NODRITA and in 1996, he obtained the position of Professor of Physics at Loughborough University. He is a Member of New York Academy of Sciences and Member of Editorial Board, Advances in Condensed Matter Physics. Prof. Kusmartsev is a very valued researcher that has presented within ENEC conferences several thought-provoking articles: Modelling a network where the opinion of each unit varies according to a majority ruling of its neighbouring units, A Polynomial Distribution Applied to Income and Wealth Distribution, Bose-Einstein distribution of money in a free-market economy, Two Interdependent Binary Opinion Networks, Econophysics: how can we describe a healthy economy and predict a financial crisis, When Rich Get Richer then Arises Financial Crisis and Bose-Einstein Condensation in a Wild Economy.

Having the Romanian dr. Elvis Oltean as co-author, Prof. Kusmartsev, in A study of methods from statistical mechanics to income distribution, has had as a purpose to form a database concerning income from dissimilar countries both developed and underdeveloped, and apply methods from Statistical Mechanics to find the causes of macroeconomic evolutions. The researchers tried Fermi-Dirac distribution, Bose-Einstein distribution, and occasionally Boltzmann-Gibbs distribution in order to determine which is optimal for income distribution. The best fit to the data was observed in the case of Fermi-Dirac distribution [27].

A regretted scientist with interesting contributions for ENEC was the late **Karl Kürten**, from Vienna University, who has published in HIJENE: „From Maxwellian elastic collisions to intimately connected kinetic wealth exchange models, „Competition between two interdependent binary opinion networks: the role of opportunists and contrarians, „Coexistence of opportunists, contrarians and inconvincibles in binary opinion networks, Elastic collisions of hard spheres versus wealth exchange interactions.

In When rich get richer there arises financial crisis and Bose-Einstein condensation in a wild economy, Kürten K. E., having as co-author Professor F. V. Kusmartsev, has modelled one of the main laws of the wild market where rich get richer, while poor get poorer. They have proved that in a wild market arises a phenomenon analogous to a Bose-Einstein condensation, where many agents lose all their money, while other agents are fighting to become richer. They have observed that the financial crisis is the time when the majority of population is excluded from trading or from the money exchange process [28].

Serge Galam, a renowned French researcher, with a double Ph.D. in Physics (Paris and Tel Aviv) is now a research director at CNSR and the inventor of a new border science-Sociophysics. He has presented at ENEC conference the communication Market Efficiency. Anticipation and the Formation of Bubbles Crashes. He has introduced a dynamical model for the formation of bullish or bearish trends driving an asset price in a given market. Initially, each agent decides to buy or sell according to its personal opinion; its choice is then determined by a local majority rule including itself. Whenever the selected group is unsure on what to do, the choice is determined by the local group belief with respect to the anticipated trend at that time. When an optimistic belief prevails, the market mechanisms have a bullish dynamic, with a big discrepancy between the fundamental value and the market value, which in turn creates a speculative bubble. However,

in the end, private opinions take over again and invert the trend quickly, creating a sudden bearish trend, leading sometimes to a market crash [29].

Matti Estola is an esteemed scientist coming from the University of Eastern Finland, Faculty of Social Sciences and Business Studies; Joensuu Campus. He has honored ENEC conference with his presence from the first edition in 2008. Some of the most interesting papers published in HIJENE journal were: Measuring the Growth and the Structural Change in a Multi-Sector Economy, Modelling the Reasons for Firm's Growth: A Control Theoretic Approach, Neoclassical and Newtonian theory of production: an empirical test, Newtonian and Lagrangian mechanics of a production system. In a recent article, Estola and Dannenberg have defined the economic correspondents for kinetic and potential energy of production and mutually coherent Newtonian and Lagrangian frameworks for modelling production and observed that the neoclassical theory corresponds to zero-force situation, when the potential energy of the production system is in its minimum. The neoclassical framework assumes that firms produce at constant positive profit maximizing flow of production. Estola and Dannenberg's framework adds dynamics in the neoclassical theory and includes in it cases like firms' permanent growth, business cycles, and bankruptcies. [30]

Alain Le Méhauté (b. 1947) is a highly appreciated French engineer-chemist and inventor, who has occupied several distinguished professorial positions at University of Nantes, and at the University of Paris-Sud, France. Prof. Le Méhauté has published several articles in HIJENE journal. In A trail between Riemann hypothesis and the founts of currency, Le Méhauté observes that by reducing the currency to a simple factor of dynamics equilibrium between fungible goods, the classical theories cannot grasp its complexity. Therefore, Le Méhauté proposes a deepening of the assumption in which the currency is, within the complex system of an economical analytics, incomplete in its nature, the non-causal part of a categorical exchange herein mathematically defined. He makes an analysis of the Riemann Hypothesis and highlights the mismatching between mathematical and Econophysics models and opens the way for a conceptual breakthrough that nevertheless stays based on zeta function [31].

Irina Dmitrieva is an Associated Professor of the Odessa National Academy of Telecommunications, Ukraine. She participated to almost all editions of ENEC with interesting articles, such as Diagonalization problems in the classical Maxwell theory and their industrial applications, Comparative analysis of electromagnetic field study using operator

diagonalization methods, Industrial problems of technical electrodynamics and analysis of the inverse matrix operator existence for the symmetrical differential Maxwell system, Operator diagonalization procedure and its numerical realization.

Many industrial problems in technical electrodynamics are described by the so called symmetrical differential Maxwell system, used in signal transmissions in the different kinds of media and analogous multidimensional circuits as well. Dmitrieva makes a study of the aforementioned Maxwell system by the combined analytic method that is in conformity with classical results and is simpler in practical application. She proposes the method of „diagonalization process that reduces the symmetrical Maxwell system to the equivalent totality of scalar equations regarding the unknown components of the electromagnetic vector field functions [32].

One interesting thing is that Romania is probably the first country in the world that has published in an official a metric that is the invention of an econophysicist, the **h-index** of Jorge E. Hirsch. In 2005, Hirsch, a physicist at UCSD, proposed a tool for determining theoretical physicists' relative quality of (known today as the Hirsch index). It is, in fact, a metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar. Ten years later, the Romanian Education and Research Minister issued the Order no. 3185/ February 2015 approving the Methodology for allocating budget funds for basic funding and additional funding to institutions of higher education in Romania, 2015. The mathematical formulas of the Hirsch index are published in this official regulation that is compulsory for all academics working in the public universities of Romania, who get their funds in correlation to their performances calculated according to h-index. It is, probably, an outcome that, probably, Jorge E. Hirsch has not foreseen: that the Romanian professors will get their money in correlation with the index he has invented…

4. Conclusions

This paper was devoted to the Econophysics, an interdisciplinary science, applying theories and methods initially developed by physicists endeavoring to solve problems in economics. The progress of the computer science made available large amounts of financial data; besides, under the pressure of the globalization, characterized by huge amounts of assets

being traded worldwide, and under the pressure of manifold types of crises, new methods of research were straightaway needed in economics.

At the border between the twentieth and twenty-first century emerged a rising interest for Econophysics, expressed through the publication of a big number of articles and books in this domain, as well as through a growing the number of international conferences and symposiums in the domain of Econophysics. This innovative science applies in an original way, theories and approaches, earlier formulated by physicists (such as statistical mechanics, power laws, stochastic processes and nonlinear dynamics), in order to solve problems in economics and markets. Physics theories and models that have been applied in economics until now are, among others, the kinetic theory of gas, chaos theory, statistical mechanics, fluid dynamics, diffusion theory, classical mechanics, quantum mechanics, stochastic processes, cellular automata, nonlinear dynamics, neural networks, pattern recognition, theory of turbulence, random matrix theory, string theory etc.

However, few theories have been taken seriously by economists, officials, legislators, so, they remain in an abstract world, unexploited in the real life, with one notable exception-the financial markets (stocks, options, currencies trading etc.), where, in the last three decades, physicists have proved to be successful thanks to their scientific background.

Physicists frequently are tempted to model economic interactions similar to collisions of atoms in gases; they simplify economic and social reality so much, that not a single serious economist can accept their theories or take them seriously at such extent to apply their ideas in their daily activity. Still, physicists come with no preconception and often, with a lot of enthusiasm and original viewpoints, with good calculus skills, and these strong points are, definitely, a good base for scientific discoveries.

Nowadays, in the world, several universities offer tuition in Econophysics, since more and more people are willing to study this cutting-edge and sometimes intriguing domain. Also, more and more people join official and unofficial forums dedicated to this science, mostly through the means of Internet technologies. Conferences on Econophysics have become a common place for researchers to meet and change ideas and try to find laws, patterns, models for such a fascinating and complex science, Economy, a science that is strongly connected to the advancement of the society, of the technologies, of the believes, of the availability of natural and human resources, even of the climate.

Romania can be considered a genuine forerunner of Econophysics, thanks to many scientists activating in this domain and to the Econophysics, New Economy and Complexity International Conferences (ENEC), that started in 2008 and took place every year in Bucharest, without any interruption, at Hyperion University. Throughout a decade, this annual conference has been a good framework for interesting theories, and ideas for many researchers coming from different countries-Austria, Finland, France, India, Iran, Moldova, Portugal, Romania, Russia, Serbia, United Kingdom, Ukraine etc.

Econophysics is, in conclusion, an emerging science that will, most certain, make available original theories in the future years, provided that economists and physicists overcome their lack of communication and work together for developing viable models, appropriate to be applied in the real economic life.

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