Володимир Соловйов,
доктор фізико-математичних наук, професор,
Криворізький державний педагогічний університет
Андрій Матвійчук,
доктор економічних наук, професор,
Київський національний університет імені Вадима Гетьмана
Андрій Бєлінський,
студент фізико-математичного факультету,
Криворізький державний педагогічний університет

ЕКОНОФІЗИЧНІ ПІДХОДИ В МОДЕЛЮВАННІ ФІНАНСОВИХ РИНКІВ

Ключові слова: міждисциплінарність, еконофізика, складність, ентропія, хаос, необоротність, неврівноважність

Vladimir Soloviev,
D.Sc., professor,
Kryvyi Rih State Pedagogical University
Andriy Matviychuk,
D.Sc., professor,
Kyiv National Economic University
Andrii Bielinskyi,
Student of the Physics and Mathematics Faculty,
Kryvyi Rih State Pedagogical University

ECONOPHYSICS APPROACHES IN FINANCIAL MARKET MODELING

Key words: interdisciplinarity, econophysics, complexity, entropy, chaos, irreversibility, non-equilibribum

Financial markets have been attracting the attention of many scientists like engineers, mathematicians, physicists, and others for the last two decades. Such vast interest transformed into a branch of statistical mechanics -– econophysics [1].

This study is dedicated to the description of the key paradigm in this interdisciplinary research: informational, (multi-) fractal, chaos-dynamic, recurrent, irreversible, based on complex networks, quantum.

Complexity is a multifaceted concept, related to the degree of organization of systems. Patterns of complex organization and behavior are identified in all kinds of systems in nature and technology. Essential for the characterization of complexity is its quantification, the introduction of complexity measures, or descriptors. Also, we may measure the complexity of the system by using entropy indicators. After the fundamental paper of Shannon [2] in the context of information theory, where entropy denoted the average amount of information contained in the message, its notion was significantly redefined. After this, it has been evolved along with different ways and successful enough used for the research of economic systems [3-4].

The economic phenomena that cannot be explained by the traditional efficient market hypothesis can be explained by the fractal theory proposed by Mandelbrot [5]. Multifractals are a type of fractal, but they stand in contrast to the monofractals. The point of a multifractal analysis is to construct the distribution of different fractal dimensions of the system.

The evolution of the system exhibits sensitive dependence on initial conditions. It means that initially close trajectories that evolve may rapidly diverge from each other and have totally different outcomes. Lyapunov exponent is a measure of the exponential rate of nearby trajectories in the phase-space of a dynamical system. In other words, it quantifies how fast converge or diverge trajectories that start close to each other, quantifying the strength of chaos in the system. Using this measure, it is possible to define chaotic region, including a possible transition between unstable and stable periods.

The CLT [6], which offers the fundamental justification for approximate normality, points to the importance of alpha-stable distribution: they are the only limiting laws of normalized sums of independent, identically distributed random variables. Gaussian distributions, the best-known member of the stable family, have long been well understood and widely used in all sorts of problems. However, they do not allow for large fluctuations and are thus inadequate for modeling high variability. Non-Gaussian stable models, on the other hand, do not share such limitations. In general, the upper and lower tails of their distributions decrease like a power function. Consequently, a probability model with a power tail can be suitable for identifying processes with extreme events. It was discovered that alpha-stable distributions fit better than the Gaussian distribution to financial and spot markets. It is still debatable whether Lévy stable distribution is applicable since there is not enough theoretical material, and there is not a universal analyzing method for estimating parameters of Lévy stable distribution.

Another approach deals with recurrence behavior in the system. Recurrence plot (RP) [7] have been introduced to study dynamics and recurrence states of complex systems. When we create RP, at first, from recorded time series we reconstruct phase-space trajectory. The dots within RP, representing the time evolution of the trajectories, exhibit characteristic large-scale and small-scale patterns. For a qualitative description of the system, the graphic representation of the system suits perfectly. However, the main disadvantage of graphical representation is that it forces users to subjectively intuit and interpret patterns and structures presented within the recurrence plot. In this case it is better to use recurrence quantification analysis.

The irreversibility of time is a fundamental property of non-equilibrium dissipative systems, and its loss may indicate the development of destructive processes [8]. The irreversibility of time series indicates the presence of nonlinearities in the dynamics of a system far from equilibrium, including non-Gaussian random processes and dissipative chaos.

Complex networks include electrical, transport, information, social, economic, biological, neural, and other networks [9]. The network paradigm has become dominant in the study of complex systems since it allows you to enter new quantitative measures of complexity not existing for the time series.

In our paper [10], we have suggested a new paradigm of complex systems modeling based on the ideas of quantum as well as relativistic mechanics. It has been revealed that the use of quantum-mechanical analogies (such as the uncertainty principle, the notion of the operator, and quantum measurement interpretation) can be applied to describing socio-economic processes.

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