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QUANTUM ECONOPHYSICS – PROBLEMS AND NEW CONCEPTIONS

This article is dedicated to the econophysical analysis of conceptual fundamentals and mathematical apparatus of classical physics, relativity theory, non-relativistic and relativistic quantum mechanics. The historical and methodological aspects as well as the modern state of the problem of the socio-economic modeling are considered.

Keywords: *econophysics, quantum mechanics, indeterminancy principle, quantum econophysics.*

The attempts to create an adequate model of socio-economic critical events, which, as it has been historically proven, are almost permanent, were, are and will always be made. Actually, it is a supertask, impossible to solve. However, the potentially useful solutions, local in time or other socio-economic logistic coordinates, are possible. In fact, they have to be the object of interest for a real and effective economic science.

Econophysics is a young interdisciplinary scientific field, which developed and acquired its name at the end of the last century [1]. Quantum econophysics, a direction distinguished by the use of mathematical apparatus of quantum mechanics as well as its fundamental conceptual ideas [2–7] and relativistic aspects [8,9], developed within its boundaries just a couple of years later, in the first decade of the 21-st century.

According to classical physics, immediate values of physical quantities, which describe the system status, not only exist, but can also be exactly measured.

Although non-relativistic quantum mechanics doesn’t reject the existence of immediate values of classic physical quantities, it postulates that not all of them can be measured simultaneously (Heisenberg uncertainty ratio).

Relativistic quantum mechanics denies the existence of immediate values for all kinds of physical quantities, and, therefore, the notion of system status seizes to be algoristic.

The current research takes into account historical and methodological aspects as well as current critical state of the problem of socio-economic modeling and is aimed at analyzing the conceptual fundamentals of classical physics, relativity theory, non-relativistic and relativistic quantum mechanics.

The new scientific field develops only when necessary conditions form and the need in concentration of the community efforts appears. Quantum econophysics is no exception.

XX century is the age of triumph of new theoretical physics, relativity theory and quantum mechanics, which not only explained new events observed in macro- and microworld, but also considerably changed fixed philosophical concepts, based on so-called common sense and classic physical ideas.

Although new concepts were established technologically, as an instrument, in physics, in our opinion the possibility and potential of their use in describing socio-economic systems is yet to be fully recognized.

One of the most important problems, which should be related to the competence of quantum econophysics, consists in tracking the real or possible effects of these concepts on problem-setting in mathematical modeling of socio-economic processes and interpretation of subsequent results.

Approaching physics as the way to predict the results of experiments is good enough for physics as it is. However the transition of its notions and mathematical apparatus to systems of different nature requires obligatory in-depth analysis of its initial concepts.

In classical physics it is assumed that key physical quantities can be considered as quantities that possess a continuous series of values and exist regardless of measuring procedures applied. At the same time:

– there are immediate values of physical quantities that describe system status;

– there are measuring procedures that allow the evaluation of immediate values of these physical quantities;

– the influence of measuring procedure on the values of the measured physical quantity can be as small as we like.

Non-relativistic quantum mechanics is based on experimental facts that indicate the following:

– the indeterminancy principle takes place, particularly there is no exact notion of the particle trajectory;

– physical quantities can possess specific values, e.g. the spectrum of allowed values can be discrete;

– similarly to classical physics, it assumes that physical quantities can have immediate values, however, not every set of values (for example, signal and particle coordinate) can be measured simultaneously;

– measuring procedure has a certain level of influence on results of the measurement, and the system status appears to be somewhat undefined after the evaluation;

– any system is open, since the wave function, used to describe system status in quantum mechanics (its existence is postulated), is formally defined and continuous in space.

Unfortunately, unlike classical, even non-relativistic quantum mechanics lacks clearness, is not confirmed by «common sense», and is left for theoretical physicists and specialists of certain applied fields to study. Therefore we find it necessary to give here one of its possible axiomatics, which includes six postulates.

Not touching on mathematical aspects and omitting their details, but emphasizing conceptual moments, we can formulate these postulates in the following way:

Instead of the classical notion of «physical quantity L» a new fundamental notion «operator of the physical quantity $\widehat{L}$» is introduced.

Possible (allowed) values of the physical quantity L are a consequence (a result) of solving a mathematical problem for eigenvalues λ of an operator of the physical quantity $\widehat{L}$:

$$\widehat{L}\varphi = \lambda\varphi .$$

To describe the system status a new notion is introduced – normalized wave function ψ :

$$\int \psi^* \psi d\tau = \int |\psi|^2 d\tau = 1 .$$

A new quantity – the average value of a physical quantity $<L>$ corresponds to the classical value of the physical quantity L in the state with the normalized wave function and is defined by the ratio:

$$<L> \ = \int \psi^* \hat{L} \psi d\tau .$$

The system evolution in time is characterized by the evolution of its normalized wave function, defined from the solution of the Schrödinger equation:

$$i \cdot \hbar \frac{\partial \psi}{\partial t} = \hat{H} \psi .$$

In the system of identical particles, all particles are indistinguishable.

The above-listed six postulates of quantum (non-relativistic) mechanics, are to some extent analogous to the laws of classic Newtonian mechanics, and make up the basis for the whole theoretical apparatus and practical applications. For instance, with the help of elementary calculations it can be shown that postulates (1) –(4) give us the fundamental uncertainty ratio for coordinates and velocities (or signals):

$$\Delta x \cdot \Delta v \geq \frac{\hbar}{2m}; \ \left(\Delta x \cdot \Delta p \geq \frac{\hbar}{2} \right), \qquad (1)$$

where Δx i Δv (Δp) are mean-square measurement faults for x coordinate and velocities $v = \dot{x}$ (signal $p = m\dot{x}$) of the particle with m mass.

From the (1) ratio five, important from the conceptual point of view, conclusions are received:

neither the particle coordinate, nor its velocity can have accurate values, because when $\Delta x = 0$ velocity uncertainty Δv, and therefore velocity itself become infinite, when $\Delta v = 0$ the particle turns out to be completely delocalized i.e. can be present in any point of the physical space;

there is no notion of limit:

$$v(t) = \dot{x}(t) = \lim_{\Delta t \to 0} \frac{x(t) - x(t - \Delta t)}{\Delta t}; \qquad (2)$$

the velocity and coordinates of the particle that define its state at a certain moment in time t in classical mechanics can be defined only approximately if Δt is finite and big enough;

in reality there is no continuous classical trajectory – it is an approximate notion that has sense only in case of big enough intervals Δt between neighbouring measurements of particle location;

deliberately approximate prediction of particle behaviour, defined by the couple of classical phase variables ($x(t), v(t)$), is possible only when its history, i.e. aftereffect, is taken into account, because:

$$v(t) \approx \frac{x(t) - x(t - \Delta t)}{\Delta t} = \frac{1}{\Delta t} x(t) - \frac{1}{\Delta t} x(t - \Delta t) \qquad (3)$$

and depends on both $x(t)$ and $x(t - \Delta t)$.

In relativistic quantum mechanics there is a novel fundamental statement which says that every measuring procedure takes a certain finite time Δt, therefore physical quantities have no immediate values. Meanwhile the uncertainty of the dynamic physical quantity measurement increases with the reduction of the measuring time and is finite in case of any finite Δt, whereas the value itself can be related only to the whole time interval [8,9].

Thus the relativistic quantum uncertainty principle for the signal is defined by the ratio:

$$\Delta p \cdot \Delta t \sim \hbar / c, \qquad (4)$$

where c is the light speed. From (4) we can see that the exact value of the particle signal can be acquired only at the time of measurement which equals infinity, and that means that only the signal of a free particle, which remains in such (free) state for the infinite time, can be defined precisely.

From all above-listed we can make a conclusion that quantum physics accepted new paradigms of mathematical modeling quite a long time ago. Operator of the physical quantity (operator – mathematical image of a procedure, action) becomes the initial and fundamental notion, the description of its dynamics becomes deliberately discrete and approximate. It becomes impossible to predict future not taking into account the aftereffect, i.e. the memory.

The possibility of introducing economic equivalents of physical quantities in order to describe socio-economic processes using the quantum uncertainty principle is shown in our works [6,7].

Using quantum-mechanical econophysic analogies, and having in mind general principles of system analysis, we suggest the following, logically interconnected, concepts, that have to make up a foundation for complex system modeling, socio-economic processes, being a part of them:

The priority of the measuring procedure against its result;

Necessary finite duration of any measuring procedure, including computer prediction (as a specific procedure of an indirect measurement) and its unavoidable influence on system status and its future behavior;

Approximate and derivative nature of the «immediate values of state variables» notion and «system status», as a necessary consequence;

The principle of uncertainty for system state variables and its fundamental connection with the duration of the measuring procedure;

Discrete time and space as well as all other quantities, connected with system dynamics, in case of its formalized description;

Aftereffect (memory) as a fundamental property of any dynamic system, which is necessary for the description of system dynamics;

Rejection of infinity as a conceptual notion, which leads to a logically unsolvable paradoxes of complex system behavior;

The principle of time irreversibility, on which the human mental ability to make any logical conclusions is based;

Openness, hierarchy and emergent nature as basic system principles of an adequate description of real complex systems.

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Квантова еконофізика – проблеми та нові концепції

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Дана стаття присвячена еконфізичному аналізу концептуальних основ та математичного апарата класичної фізики, теорії відносності, нерелятивістської і релятивістської квантової механіки. Обговорюються історичні і методологічні аспекти та сучасний стан проблеми соціально-економічного моделювання.

Ключові слова: еконофізика, квантова механіка, принцип невизначеності, квантова еконофізика.

Квантовая эконофизика – проблемы и новые концепции

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Данная статья посвящена эконофизическому анализу концептуальных основ и математического аппарата классической физики, теории относительности, нерелятивисткой и релятивисткой квантовой механики. Обсуждаются исторические и методологические аспекты и современное состояние проблемы социально-экономического моделирования.

Ключевые слова: эконофизика, квантовая механика, принцип неопределенности, квантовая эконофизика.