Theoretical aspects of synergetic model formulation in the economic systems innovative-investment development

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Different approaches to the interpretation of the category "investment" and "innovation" have been presented and evaluated in this article. The basic characteristics and particular qualities of investigated definition have been mentioned. The article shows that the basis of theoretical understanding of the investment and innovation process is showing of any economic system as a complex open system, which allows to use the principles of synergetic campaign for the development of effective models of transition systems from one state to another, qualitatively new state, and also makes it possible to search for universal principles of self-organization and evolution of complex economic systems. The author of the article suggests the model which allows describing qualitatively the self-consistent evolutionary action of investment and innovation processes of economic systems. In the framework of the adiabatic approximation shows the solution of the model, corresponding to the equation of the Landau-Khalatnikov synergy potential coincides with a similar potential for the usual Lorentz system.

Keywords: the economic system, investment, innovation, category, model.

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Problem definition. Owing to the global crisis and hyperdynamic improvement characterizing market environment, there is a constant necessity to form and introduce a model of economic system development. It can provide high and stable rates of the economic growth, solve some social and ecological problems, and provide competitiveness of the national economy. One of the key tasks concerning economic system development strategy consists in the pre-orientation in the direction of the innovative-investment development. For example, State target program of Ukrainian industry development till 2017 [1] points out that innovative-investment activity of the industrial complex will provide fast growing of the national wealth and labour productivity, increase of the gross domestic product, contribute to economic and social development of the society. On the ground of it, the investigation of the self-consistent evolutionary investment and innovations behavior is very urgent question and needs profound analysis.

Analysis of the latest investigations and publications. A lot of scientists study the question about innovative and investment activity. Among outstanding foreign scientists whose works related to this question are: I. Ansoff, P. Druker, M. Porter, B. Santo, K. Frimen, J. Shumpeter, B. Twiss. Leading native researchers, who study the mentioned problem are M. Tugan-Baranovsky, I. Blank, J. Boiko, A. Gerasymovych, P. Mykytyuk, M. Pushkar, S. Ilyashenko, R. Fatchudinova and others. But native and foreign scientific sources have not enough developed conceptual grounds of the synergetic analysis concerning investment-innovative processes in the economic systems that would make for the theoretical basis and

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development of the effectiveness analysis methodology and investment-innovative processes regularity.

Aim and object of the article is to conduct critical analysis and to generalize theoretical approaches to determine main point and main content of the categories «innovations», «investment» and to create the descriptive synergetic model of the innovative-investment processes in the economic systems.

Presentation of the main investigated material. In economic literature term «innovation» has many definitions depending on the subject and object of the scientists' investigation. J. Shumpeter has firstly used the term «innovations» in 1939 and examined them as "changes with the purpose to introduce and to use new types of consumer products, new manufacturing and transport facilities, markets and form of organisation in the manufacture" [2].

According to the Act of Ukraine "On innovative activity" innovations are the newly created (applied) and (or) improved competitive technologies, production or service and also organizational and technical decisions of productive, commercial character, that will essentially improve the structure and quality of production and (or) social sphere [3].

V. G. Medinsky and S. V. Ildemenov explain innovation in their work as «object, applied in industry as a result of conducted scientific research or discovery, qualitatively differed from the previous analogue» [4]. L. L. Antonyuk, V. S. Savchuk, A. M. Poruchnyk examine innovation as a new phenomenon, pioneer work or any change, that is inserted by the economic agent into own work in order to increase the competitiveness in the home and foreign markets [5]. F. Walentyn points out in his work that innovations are changes in the original structure of operating mechanism, i.e. change of its inner structure into new state [6]. L. Woldachek notes, that innovations are objective changes in the enterprise as a system (quantitative, qualitative in any enterprise activity) [7]. A. I. Prigozhyn describes innovations as focused actions, which introduce new relatively stable elements into the environment [8]. Thus all definitions "innovations" may be symbolically divided into two approaches: statistic approach considers innovation as a form of the new technique (production), technology, new method etc; dynamic approach considers innovation as a process to replace existing technologies with new ones [9].

Besides, special attention is paid to the conceptual mechanism of the term "investments". The Act of Ukraine «On investment activity» determines investments as all kinds of the property and intellectual valuables, contributed into business and other activities objects, which result in profit or social effect [10].

The modern economic Raisberg's dictionary describes investments as long-term contribution of the state and private capital in different enterprises, projects, social and economic programs, innovative projects [11] in the native land or abroad in order to receive profit. From S. Fisher's, R. Dornbush's and R. Shmalenzy's points of view investments are expanses to create new capacities in machine producing, financing of the house, industry and agriculture building, and resources [12]. L. Gitman, M. Johnk consider investments as the way to allocate money, that has to provide preservation or growing of its cost and (or) to cause positive size of the profit [13]. O. I. Kovtun describes investments according to the economic and financial categories. Economic category understands investments as expanses to create, spread, reconstruct the main capital, and as expanses for changes of the working capital. Investments as a financial category are all kinds of property, financial and intellectual valuables, which are contributed into the objects of enterprise and other activities, social infrastructure in order to get profit or social effect [14]. A. M. Margolin and A. J. Bystryakov

suppose that «investments are money, objective bank deposits, shares, stocks and other paper holdings, technologies, machines, equipment, property and other rights, that have money value and contributed in enterprise or (and) other activities objects in order to get profit and (or) to achieve another profitable effect» [15]. A. W. Mertens in his work notes that investments are the part of the total costs, consisted of costs for the new production, investments for new housing, and growth of the business stocks [16].

Theoretical analysis of the suggested definitions allows to agree with P. P. Mykytyuk's opinion that these categories are interconnected owing to their origin [17]. Scientists point that innovations can't be formed without any additional and constant contributions of the investment resources, and investments have economic sense only when they are oriented to realize an idea to create new technique, technology, that will make for new possibilities to get profit. Thus, we may distinguish familiar features, peculiar to these categories (table 1).

Table 1 – Comparative characteristics in determination of «innovations» and «investments»

Feature	Characteristics
Purpose	Getting of the useful effect: economic; ecological; social or another one
Direction	Positive influence to improve peculiarities of the activity objective
Time / display	Long-term character (getting of the effect in the middle or long-term period)
Introduction	Result of the complex using of decision elements (systematic scientific-methodic development, research programs etc)
Uncertainty / risk	Depend on uncertainty factors, which are the reason of risks

Theoretical ground to understand investment-innovation process is to represent an economic system as a complex open system, state of which depends on many factors, and thanks to the self-consistent conduct a little change of one parameter, may cause great change of the whole system development.

The process of the open system development is based on the back action connections, which are the base of the self-regulation, adaptation to the way of changeable living, and therefore to the development. For example, positive back connection keeps tendencies to change different parameters in the system. On the one hand, a positive back connection leads only to damage, loosening, uncertainty and makes the system lose its control, but on the other hand, uncertainty is not always a negative phenomenon. I. Prygozhyn [18] underlines that uncertainty may be the factor of the sustainable and dynamic development. Only far from balance systems, being unstable, can spontaneously organize and develop themselves. In other words, uncertainty also means development owing to bifurcations. There can appear change of economic systems goals, objectives and structure in the bifurcation point. During transformational process there may be adaptation to new conditions, changes in functional mechanism of the economic system or the system gets some damages, i.e. it doesn't achieve new level and as a result we can see stagnation of the system. Back negative connection vice versa reacts against changes of the outgoing parameter, i.e. it is focused on preservation, stabilization of the necessary parameter and thereafter system state.

Open system state is characterized by many freedom stages: unlimited variety of the microscopic stages (enterprises, cooperation etc) and some macroscopic ones (state, regions). According to the theory of phase transitions the cooperative system behavior is pictured by the

only one freedom degree, i.e. hydrodynamic mode, amplitude of which is down to the order system parameter and recognizes self-organization [19]. Thus, development of the complex nonlinear dynamic systems is determined with oscillation amplitude of the system elements resulting marks [20]. One should point, while studying and modeling processes in the economic systems many parameters can't be expressed quantitively, because they have qualitative characteristics and some of them can't be objectively defined. As a result, the concept of synergetic economics becomes widely used. Due to its matter synergetics is science about self-organization of the open fixed systems. Synergetic approach in the economic systems investigations leads to develop active models to describe the transfer of the system from one more qualitative state into another, and allow to search universal self-organization principles and evolution of the complex economic systems (to form the law of self-preservation and evolutionary development).

While studying the self-coordinated behavior of the economic systems parameters Lorenz synergetic system is often used:

$$\tau_\sigma \dot{\sigma} = -\sigma + A_\sigma \varepsilon, \quad (1)$$

$$\tau_\varepsilon \dot{\varepsilon} = -\varepsilon + A_\varepsilon \sigma T, \quad (2)$$

$$\tau_T \dot{T} = (T_e - T) - A_T \sigma\varepsilon, \quad (3)$$

where σ – is being the order parameter characterizing system state, ε – the conjugate field, T – the control parameter, $\tau_\sigma, \tau_\varepsilon, \tau_T$ – are relaxation times of relevant parameter, T_e – value of external influence, A_σ, A_ε A_T – are coupling constants [21].

The system of equations (1) – (3) describe self-organizing behaviour of three degree of freedom σ, ε, T, i.e. a change of one parameter changes other two. The initial reason for this self-organization process is the positive feedback of T and σ on ε. On the other hand, the negative feedback of σ and ε on T in eq. (4) plays an important role since it ensures the system stability. Because of this feedback and existence of relaxation terms in every equation stationary states establish in the course system evolution, but under certain conditions is possible autooscillation regime and strange attractor realizes [22].

The most widely-distributed non-linear model of innovative processes is the innovation diffusion model, which uses to understand nature and organization of system administration of innovations. Diffusion process, expressed in part of release of high technology product or number of companies, acquired a market of new products, describes by logistic curve or its modifications with next equation [23]:

$$\frac{dx}{dt} = \lambda \cdot x \cdot (Y - x), \quad (4)$$

where x – is an evolution coefficient dependent on time, λ – is a parameter characterizing rate of change (evolution trend), Y – is a parameter that define limits of change in the frame of current state of the market.

Appearance of leaps on logistic curves characterizes the beginning and the end of innovative production or modification of technological plans. Although, as Borzilov specify on his work, a main limitation of such models is a lack of accounting of system creating and

subjective reasons which have an effect on innovations evolution [24]. Therefore, the usage of synergetic approach gives a chance to explain characteristics of innovation processes as avalanche-like character of beginning of developing process, the nature of leaps on logistic curves, the stochasticity.

The author proposes the following model to study the stochasticity of innovation process:

$$\frac{dx}{dt} = A + \frac{p}{N} \cdot x \cdot (N - x) - \beta \cdot x , \tag{5}$$

where x=x(t) – being a number of companies participating into the innovative process at time t; N – the total number of companies of industrial sector, p (p>0) – coefficient of increasing number of participants; A – a constant which determines an increase of participants into the innovation process; β – coefficient of nonparticipation into the innovation process β>0.

The second term in equation (5) takes into account a competition between participants in the innovation process, and the last term – rejection of innovations by companies. But no one of proposed models does not describe fundamental synergetic laws of innovation-investment development of economic systems – a sequential transition from a state of standard system's operation to self-organizing state owing to unexpected impacts of external environment.

In basis of matter of innovation and investment activity as two correlated processes we suppose that system consist of N companies, from which x≤N follow the innovation development strategy, others N-x behave at random. Suppose that amount of investments P(t) vary by $\delta P(t+\tau)$ during time τ. At this time strategically oriented partners make a decision to increase or decrease innovations on the assumption of variation of attracted investments I(t).

Therefore, random values I(t) and $\delta P(t+\tau)$ appear statistically correlated, and correlator:

$$\left\langle \delta I(t)\delta P(t+\tau) \right\rangle \equiv \lim_{T\to 0} \frac{1}{T} \int_0^T \delta I(t)\delta P(t+\tau)dt \tag{6}$$

possesses the non-zero value.

Thereby, difference between innovative-oriented and random companies is that for first the correlator:

$$C = \lim_{\tau\to 0} \left\langle \delta I(t)\delta P(t+\tau) \right\rangle \equiv \lim_{\tau\to 0} \lim_{T\to 0} \frac{1}{T} \int_0^T \delta I(t)\delta P(t+\tau)dt \tag{7}$$

has non-zero value, and for second C=0. In this case one determine the correlator as the order parameter defined the choice of strategy. Respectively, conjugate field comes to amount of attracted investments I(t), and the number x of companies with innovative strategy plays a role of control parameter [19].

Self-organizing evolution of the system defines by self-consistent equations for rate of change of main parameters dependent on their values:

$$\tau_C \dot{C} = -C + A_C I , \tag{8}$$

$$\tau_I \dot{I} = -I + A_I C x , \tag{9}$$

$$\tau_x \dot{x} = A + \frac{p}{N} \cdot x \cdot (N - x) - \beta \cdot x - A_x CI\,, \qquad (10)$$

where x=x(t) – being a number of companies participating in the innovative process at time t; N – the total number of companies, p (p>0) – coefficient of increasing number of participants; A – a constant which determines an increase number of new participants into the innovation process; β – coefficient of nonparticipation into the innovation process β>0.

The second term of equation (10) consider a competition between participants into the innovative process. The last term consider a rejection of innovations by some companies. $A_x CI$ – consider feedback of investments to the number of innovation oriented companies.

System of equations (8–10) does not solve in general case. Therefore we analyze it with an adiabatic approach $\tau_C >> \tau_I, \tau_x$, which means that order parameter C changes less rapidly and other two parameters follow its changes. So, $\dot{I} \approx 0$, $\dot{x} \approx 0$. Solving equations (9)–(10) with previous assumption and substitute corresponding variables, one can find synergetic potential V from Landau-Khalatnikov equation:

$$\tau_C \dot{C} = -\frac{dV}{dC}. \qquad (11)$$

This synergetic potential has a minimum at

$$C_0 = \sqrt{\frac{p \cdot (r-1)}{A_C A_x N A_I^2}}., \qquad (12)$$

obtained from $dV/dC = 0$, where $r = (A_C A_I N / p)(A A_C A_I + p - \beta)$. When r>1 the curve of synergetic potential has a minimum (fig. 1)

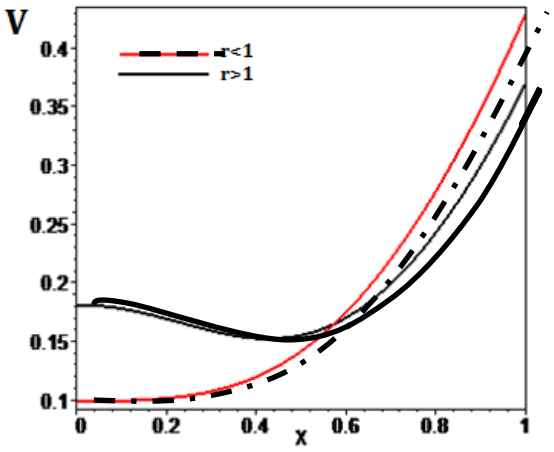

Figure 1. Dependence of synergetic potential (12) such x

Note that the potential (12) coincides with the same potential for the Lorentz system.

Conclusions. On the basis of the conducted theoretical analysis of «investments» and «innovations» there was ascertained, that likeness and interconnection of these categories are

observed in the variety of using, i.e. investments and innovations (as system-formed constituents) may be invested into different spheres (organizing, financial, social, scientific and others), but only innovative approach gives investment owned direction and leads to the maximum effect.

The suggested work represents model, that allows to describe the development of the innovative-investment process in the economic system. This is a qualitative model and doesn't pretend to the equal quantitative process view, taking place in the economic system, because it is formed with assumptions concerning self-organization of the economic parameters. However, suggested equations may help to establish the main peculiarities of the process in these systems.

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Теоретические аспекты разработки синергетической модели инновационно-инвестиционного развития экономических систем

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В работе приведены и проанализированы разные подходы к трактовке категории «инвестиции» и «инновации», что позволило выделить основные общие характеристики и особенности исследуемых дефиниций. В статье показано, что основой теоретического понимания протекания инвестиционно-инновационных процессов является представление любой экономической системы в виде сложной открытой системы, что позволяет использовать принципы синергетического похода для разработки действенных моделей перехода систем из одного состояния в другое качественно новое, а также делает возможным поиск универсальных принципов самоорганизации и эволюции сложных экономических систем. Предложена модель, позволяющая на качественном уровне описать самосогласованное эволюционное поведение инвестиционно-инновационных процессов экономических систем. В рамках адиабатического приближения показано решение данной модели, отвечающее уравнению типа Ландау-Халатникова, синергетический потенциал которой совпадает с аналогичным потенциалом для обычной системы Лоренца.

Ключевые слова: экономическая система, инвестиции, инновации, категория, модель.

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Теоретичні аспекти розробки синергетичної моделі інноваційно-інвестиційного розвитку економічних систем

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В роботі наведено та проаналізовано різні підходи до трактування категорій «інвестиції» та «інновації». На основі проведеного теоретичного аналізу даних категорій виділено основні спільні характеристики і особливості досліджуваних дефініцій.

У статті показано, що основою теоретичного розуміння протікання інвестиційно-інноваційних процесів є представлення будь-якої економічної системи у вигляді складної відкритої системи, що дозволяє використовувати принципи синергетичного походу для розробки дієвих моделей переходу систем з одного стану в інший якісно нове, а також робить можливим пошук універсальних принципів самоорганізації та еволюції складних економічних систем.

При дослідженні економічних явищ традиційно використовують графічні моделі, що дозволяє якісно простежити тенденції у розвитку економічних систем. Математичні моделі використовуються не так часто, оскільки існує певна складність в їх побудові. Причина в тому, що практично будь-яка економічна система являє складну систему, стан якої залежить від багатьох факторів. Згідно з визначенням складних систем незначна зміна одного з параметрів за рахунок самоузгодженого поведінки може спричинити істотну зміну загальної картини. Слід зазначити, що багато параметрів висловити чисельно неможливо, оскільки вони носять явний якісний характер, а деякі з них навіть не можуть бути об'єктивно виявлені. Певна складність у тому, що для кожної системи слід складати свої моделі, які будуть діяти тільки на певному проміжку часу, оскільки в процесі еволюції зазвичай з'являються нові діючі фактори.

У статті в рамках синергетичного підходу проведено аналіз нелінійних моделей економічного зростання, а саме: моделі поширення (дифузії) інновацій. Встановлено, що жодна із запропонованих моделей не описує основні синергетичні закономірності інноваційно-інвестиційного розвитку економічних систем – послідовний перехід від сану організації, в якому спостерігається нормальне функціонування системи, до стану самоорганізації в результаті непередбачуваного впливу зовнішнього середовища.

У роботі запропоновано модель, що дозволяє на якісному рівні описати самоузгоджену еволюційну поведінку інвестиційно-інноваційного процесу економічних систем. В основу даної моделі покладена система Лоренца яка є однією з найбільш універсальних моделей поведінки складної системи, значно віддаленої від рівноважного стану. Зазвичай дана система подається у вигляді диференційних рівнянь, які визначають часові залежності параметра порядку, сполученого поля і керуючого параметра. Відповідно в роботі сполучене поле зводитися до обсягу залучених інвестицій, параметр порядку до корелятора між об'ємом інвестицій та інновацій, а роль керуючого параметра відіграє число підприємств, діючих згідно певної інноваційної стратегії. У рамках адіабатичного наближення показано рішення даної моделі, що відповідає рівнянню типу Ландау-Халатникова, синергетичний потенціал якої збігається з аналогічним потенціалом для звичайної системи Лоренца.

Ключові слова: економічна система, інвестиції, інновації, категорія, модель.

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