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MANAGEMENT PROBLEMS OF INNOVATIVE TECHNOLOGIES

Andrii V. Stasyshyn[1], Markian M. Oliskevych[2], Valeriy A. Kozytskyy[3]

The article focused on the innovative technologies management problems investigation. The endogenous distribution of economic factors for research and development sectors have been evaluated in order to study the accumulation process of innovation and technologies. The research methodology is based on the system dynamics approach that gives the advantage to delve in dynamic problems for complex economic and social issues taking into account information and material delays as well as feedback and endogenous causality. The computer simulation model has been built to describe the dynamic of innovative technologies a-nd to perform the sensitivity analysis in order to investigate how change in different parameter of system affect the economic growth and its dynamic properties. The simulation results confirm that management policy decisions can change dramatically if parameters are influenced by unpredictable shocks but the behavior of technological growth does not depend on initial conditions of system if an effective management policy has been provided.

Key words: *technology, innovation, system dynamics, management problems, simulation model.*

JEL Classification*: O32, E61, H52*

Introduction. The technologies and innovation production is a crucial factor of economic stability and development for every country [1]. It is important to investigate how the allocation of resources for knowledge production is determined and what types of technologies are available. Innovative technologies are obtained as one of the type of knowledge in research and development sector and are used by all economic agents that include government and business. Many different types of technologies and knowledge have impact on economic growth and business cycle smoothness. However, the determinants of the accumulation of different types of innovation and technologies are different. Moreover, the competitive market forces cannot completely control the distribution and production of knowledge that produce innovative technologies. It depends on the nature of knowledge, as well as on such economic institutions that regulate all property rights. The degree of exclusivity affects how the distribution and development of knowledge differs from perfect competition. We can not expect that there is only one theory of knowledge growth but we can investigate the main factors that affect its accumulation and implementation. Scientists confirmed various nonlinearity and asymmetric dynamics in important macroeconomic variables that evaluated economic growth and technological development in Ukraine as well as in EU countries [2; 3].

Literature review. V. Kozyk, O. Mrykhina, O. Koleshchuk and T. Mirkunova (2018) investigated the transmission of innovative technologies from education institutions to the business and developed the instruments for decision makers how to start effective research in Ukraine [4]. Z. Aralica (2020) developed the applications related to the vital technologies in Croatia and emphasized the importance of the innovations as a necessary tools in creating of government policy management [5]. M. Oliskevych and I. Lukianenko (2020) discussed asymmetric behavior in fluctuations of unemployment and technologies development during the economic cycle over the past decade [6]. C. Ganguli, S. Shandilya, M. Nehrey, M. Havryliuk (2023) emphasized the significant growth of the cyber environment and defensive mechanisms fulfil the online safety [7]. W. Wereda (2022) focused on the role of modern technologies in producing contemporary innovative enterprises in Poland [8]. M. Odemiş (2022) studied the effectiveness of the innovative technologies that was used in business operating and discussed how beneficial they

[1] *Andrii V. Stasyshyn*, PhD (Economics), Associate Professor,
Associate Professor at Department of Economics and Public Management,
Dean of Faculty of Financial Management and Business,
Ivan Franko National University of Lviv,
e-mail: astasyshyn@gmail.com
ORCID: https://orcid.org/0000-0002-3061-0788

[2] *Markian M. Oliskevych*, Software Developer,
ELEKS Software,
e-mail: olisk@ukr.net

[3] *Valeriy A. Kozytskyy*, PhD (Physics and Mathematics), Associate Professor,
Associate Professor at Department of Mathematical Economics, Econometrics,
Financial and Insurance Mathematics,
Ivan Franko National University of Lviv,
e-mail: vaklviv@ukr.net
ORCID: https://orcid.org/0000-0001-7977-9667

were in the hospitality businesses in Turkey [9]. Scientifics estimated the different types of models that combined evaluation of long-term relationships and investigation of short-term dynamics to describe the growth of important economic indicators [10; 11]. L. Guryanova, O. Bolotova, V. Gvozdytskyi and O. Sergienko (2020) investigated the increasing of management efficiency in corporate systems taking into account a large number of destabilizing factors to support the long-term stability in proactive contour of technologies management. J. Kraciuk, E. Kacperska, K. Lukasiewicz and P. Pietrzak (2022) conducted a cluster analysis and evaluated the implementation of innovative energy technologies in EU countries [12]. A. Kaminskyi, M. Nehrey and M. Komar (2020) focused on study of investment risk evaluation [13].

The purpose of research. We develop and analyze a model to investigate an endogenous distribution of economic factors for research and development sectors in order to evaluate the accumulation of innovative technologies and provide an effective management policy.

Materials and methods. The model takes into account that the accumulation of knowledge is created in a separate research and development sector of the economy and the whole amount of resources such a capital and labor are distributed between two sectors. Research and development sector generates new ideas and produces new innovative technologies. Production function includes capital, accumulation of labor and technology that are combined deterministically to form technological improvements. To model technological progress we add additional variable to explore extra information, because we are interested in growth in long run. We also add a shift parameter to the production function to investigate the sensitivity properties and estimate the impact of parameter changes on the research and development achievement.

The production functions is presented as a Cobb-Douglas function. However, the sum of the elasticities is not necessarily limited to one. As in the Solow's model, the share of output and labor fractions are exogenous and constant in the resource and development sector. The main variables of the model are following: capital (*C*), labor (*L*), technology (*T*) and production (*X*). There are two sectors of economy. The first sector produces goods and services and the second sector is responsible for creating innovative technologies. The production of goods uses μ_L fraction of labor and technological sector uses labor fraction $1-\mu_L$ respectively. The production sector uses μ_C share of capital to produce new goods, and the $1-\mu_C$ share of capital is used for research. Both sectors have access to the whole amount of current amount of technologies *T*.

Therefore, the model includes following equation

$$X(t) = [\mu_C\, C(t)]^{1-\beta}\, [T(t)\, \mu_L L(t)]^{\beta}\ ,\ 0 < \beta < 1, \qquad (1)$$

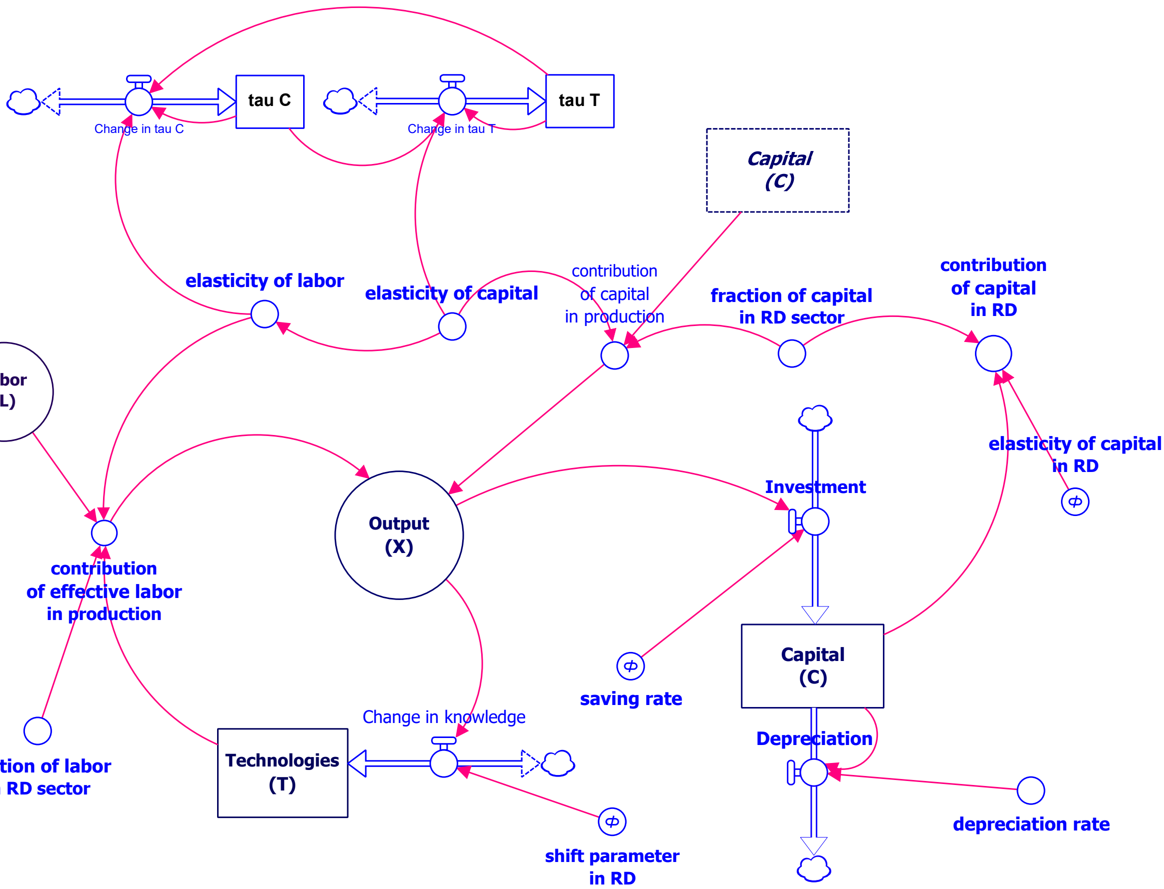

Figure 1 – System Dynamic Model of Technologies Accumulation

Source: Evaluation of the authors

where $1-\beta$ represents the elasticity of cspital in the production sector, and β is the elasticity of the efficient labor force.

The development of innovative technologies depends on the amount of capital and labor involved in the development and research sector. Therefore, the model is expanded be the following equation:

$$T'(t) = G\,[(1-\mu_C)\,C(t)]^{\rho}\,[(1-\mu_L)L(t)]^{\eta}\,T(t)^{\delta},$$
$$G > 0,\ \rho > 0,\ \eta > 0\ . \qquad (2)$$

In equation (2), δ is the elasticity of knowledge, η is the elasticity of labor, ρ is the elasticity of capital in the research and development sector. Parameter G defines how the technology growth depends on previous existing resources.

The available stock of knowledge has an impact on the achievement of research and is reflected by the parameter δ that can be positive if previous discoveries can give tools and ideas ($\delta > 0$) as well as negative because the simplest discoveries can be created in the beginning. When certain stock of knowledge is greater than zero, it is difficult to create new innovative discoveries and therefore $\delta < 0$. Thus, in equation (2) δ can have any value. The new capital depends on the production output, capital stock, savings rates and depreciation rates.

To be able to test different policy, we built a system dynamic model that represents model relationships (Figure 1).

We obtain the growth rate of innovation (τ_T) that can be determined by the equation

$$\tau_T(t) = T'(t)\,/\,T(t) = G\,(1-\mu_L)^{\eta}\,(L(t))^{\eta}\,(T(t))^{\delta-1} \qquad (3)$$

and equation for growth rate of the τ_T:

$$\tau_T{}'(t)\,/\,\tau_T\,(t) = \eta\, n + (\delta - 1)\,\tau_T\,(t). \qquad (4)$$

In result, the derivative of growth rate of innovative technologies can be described by the equation

$$\tau_T{}'(t) = \eta\ n\ \tau_T(\mathrm{t}) + (\theta - 1)\,(\tau_T(\mathrm{t}))^2\ . \qquad (5)$$

To represent the dynamics of the system that is stemmed from the model and is based on equations (1) – (5), we built system dynamic model for growth rate of innovative technologies (Figure 2). Computer simulation process has been conducted by the Stella Architect software program.

Results. We investigate the propensities of the growth for the main system variables for different values of the elasticity of knowledge δ ($\delta < 1$, $\delta > 1$, and $\delta = 1$).

In case $\delta < 1$, τ_T is displayed as a function T. The production function for technologies takes into account only positive values of τ_T because τ_T is larger than zero. For $\delta < 1$ there is $\tau_T{}'(\mathrm{t}) > 0$ for small positive values of τ_T and $\tau_T{}'(\mathrm{t}) < 0$ for large values. We obtain that τ_T converges to some equilibrium level, and this does not depend on the initial conditions of the system (Fig. 3).

We can conclude that the growth rate of technologies is an increasing function of population growth rate. Favorable population growth has an important impact on the sustainable growth of production per employee. In countries with faster population growth the increase in production per worker is not higher on average and the share of labor force in the research and development sector does not affect the long-term growth. It is expected that the growth of labor force dedicated to technological progress will lead to long-term development.

The results of modelling show that if elasticity of knowledge increases the growth rate of innovative technologies turn in exponential growth pattern and the technological progress became faster (Figure 4). We also observe much faster growth of capital (Figure 5).

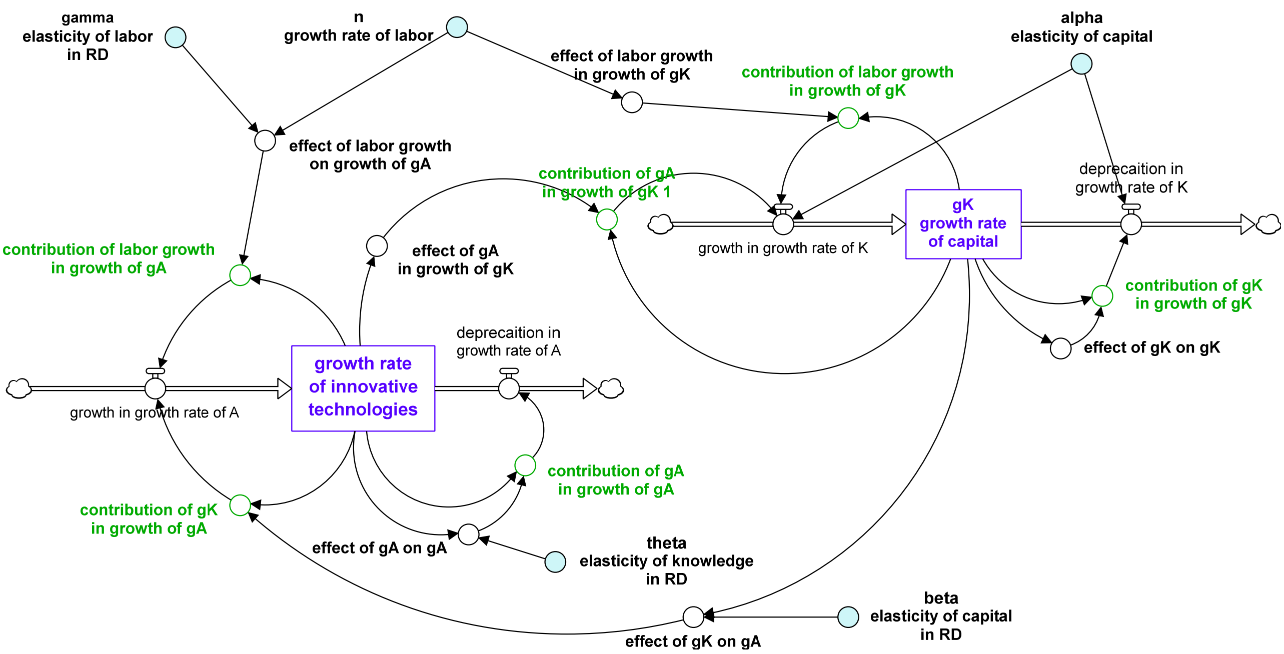

Figure 2 – System Dynamic Model of Innovative Technologies Growth

Source: Evaluation of the authors

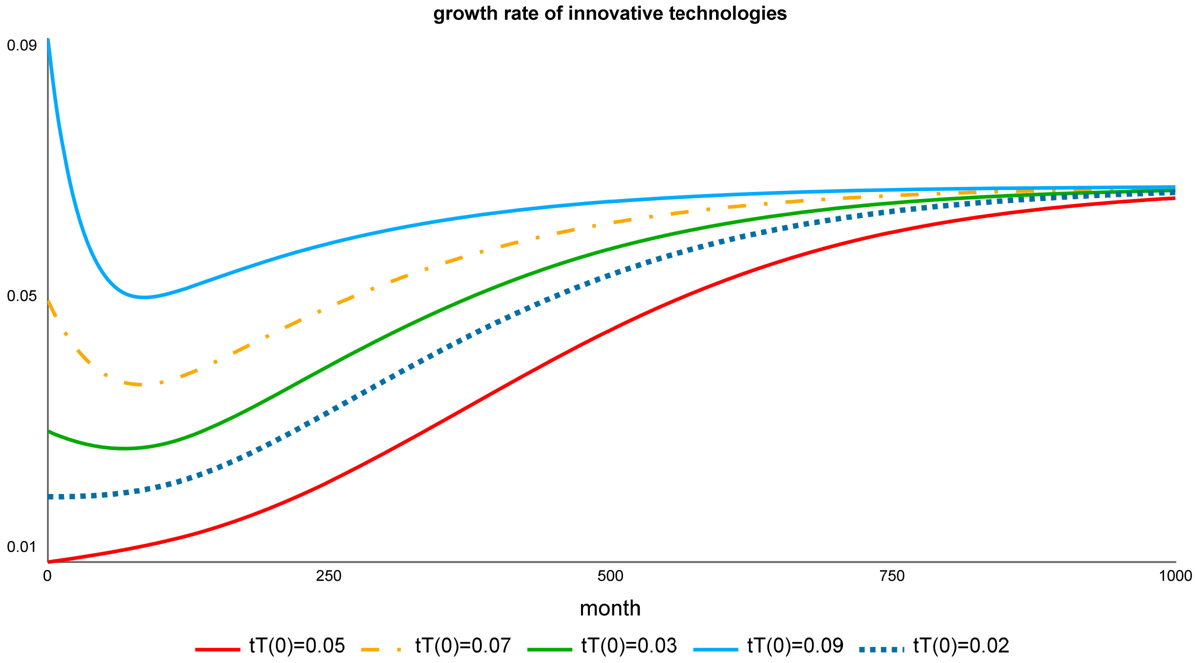

Figure 3 – The dynamic of growth rate of innovative technologies for different initial conditions

Source: Evaluation of the authors

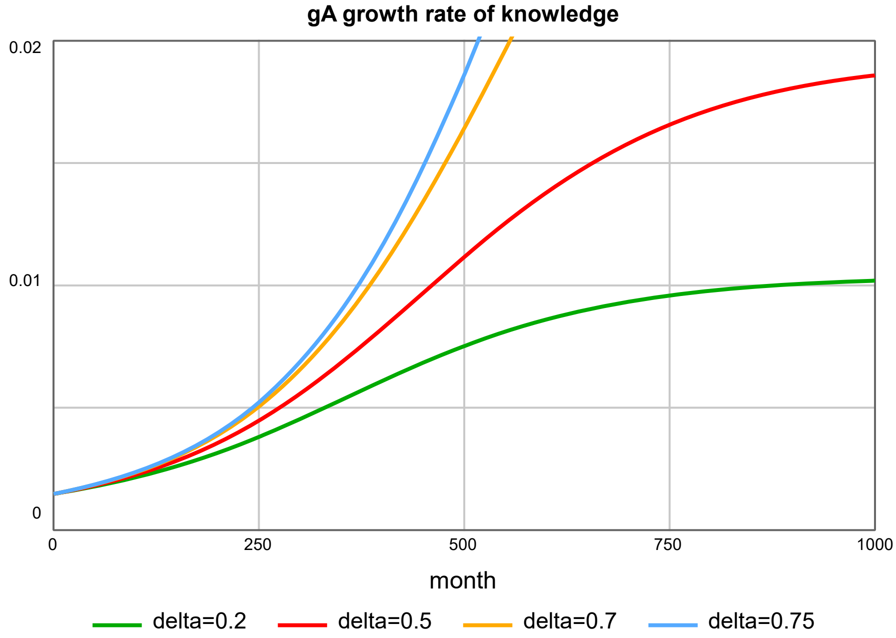

Figure 4 – Dynamics of technologies growth for different levels of elasticity of knowledge

Source: Evaluation of the authors

In case $\delta = 1$, the current information is quite productive in creating new knowledge. New knowledge is proportional to the stock. τ_T increases with time and there is a positive population growth. There is no adaptation to a balanced development path. The economy will continue to expand no matter where it starts. In this case, the goods produced in the economy are used only for consumption. Thus, μ_L is part of society's resources allocated to the production of goods for current consumption.

The third case ($\delta > 1$) is similar to a situation where new knowledge stock is always larger than the current stock. Knowledge in the production of new technologies is so useful that every small rise in its stage leads to much more new knowledge. Therefore, when the accumulation

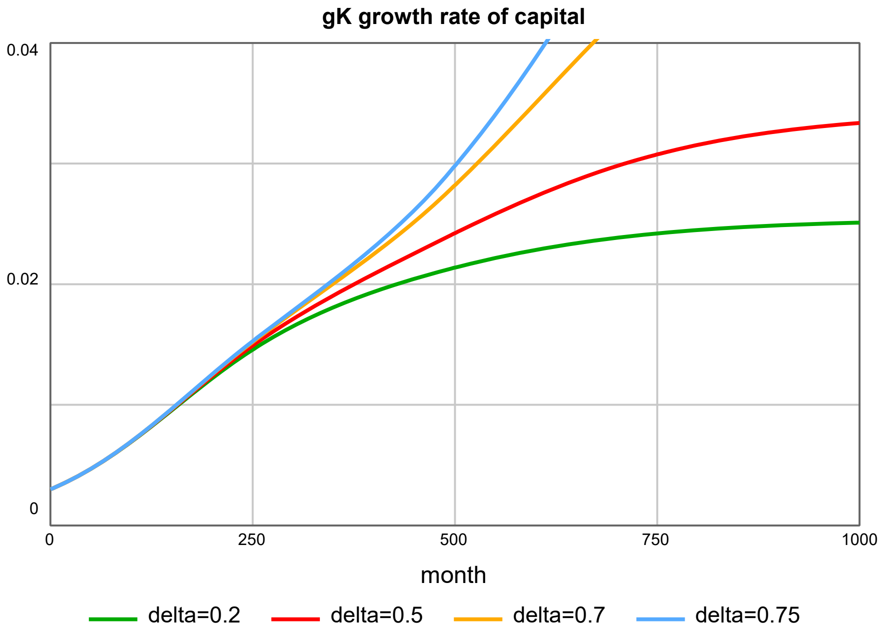

Figure 5 – Dynamics of capital growth for different levels of elasticity of knowledge

Source: Evaluation of the authors

of knowledge begins, the economic growth begins. There is a significant effect of increasing the share of the labor force involved in research and development sector. The faster τ_T grows, the faster its growth rate increases.

Conclusions. Innovation technologies management serves for getting an impact on the economic agents and the innovation process in order to encourage the creation and implementation of innovations that have practical value for the organization and produce the competitive advantages. The pattern of innovative technologies growth is particularly important in the situation with uncertainty and high risk that we observe during the war in Ukraine. The managing of innovation processes includes methods of processing information, making efficient decisions, generating innovative ideas, developing effective sequences, creating new products, influencing consumers. Most of them are brought about by research and development sector of economy, caused by the accumulation processes in result of empirical research as well as practical experience of entrepreneurs and managers.

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ПРОБЛЕМИ УПРАВЛІННЯ ІННОВАЦІЙНИМИ ТЕХНОЛОГІЯМИ

Андрій Васильович Стасишин[1], Маркіян Мирославович Оліскевич[2], Валерій Андрійович Козицький[3]

Стаття присвячена дослідженню проблем управління інноваційними технологіями. З метою вивчення процесу розроблення та накопичення інноваційних технологічних знань здійснено ендогенний аналіз розподілу економічних факторів у різних секторах економіки, зокрема секторі досліджень і розробок. Методологія дослідження базується на підході системної динаміки, який дає змогу системно вивчати динаміку складних економічних і соціальних проблем, враховуючи інформаційні та матеріальні затримки, а також петлі зворотних зв'язків та ендогенні причинно-наслідкові співвідношення. Побудовано комп'ютерну імітаційну модель для опису динаміки інноваційних технологій, проведено аналіз чутливості економічних змінних системи на зміну різних параметрів, що визначають економічне зростання та темпи росту технологічних інновацій. Управління інноваційними процесами включає методи обробки інформації, прийняття ефективних рішень, генерування інноваційних ідей, розроблення ефективних послідовностей, створення нових продуктів, запровадження сучасних засобів впливу на споживачів. Більшість з них розробляються у науково-дослідницьких секторах економіки поряд з неперервним процесом накопичення знань, що отримуються в результаті емпіричних досліджень та практичного досвіду підприємців і менеджерів. Результати моделювання засвідчують, що управлінські рішення реагують на зміну параметрів, які зазнають непередбачуваних шоків, але динаміка технологічного зростання не залежить від початкових умов системи за умови запровадження ефективної політики публічного управління. Відтак, інноваційні технології отримуються як один із видів знань у секторі досліджень та розробок і використовуються всіма економічними агентами, включаючи державу та бізнес, а конкурентні ринкові сили не можуть повністю контролювати процеси розповсюдження та виробництва знань, які створюють інноваційні технології. Характер розвитку інноваційних технологій особливо важливий сьогодні, у ситуації невизначеності та високого ризику, проблем та викликів, які ми спостерігаємо під час війни в Україні.

Ключові слова**:** *технологія, інновація, системна динаміка, проблеми управління, імітаційна модель.*

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[1] *Стасишин Андрій Васильович*, кандидат економічних наук, доцент, доцент кафедри економіки та публічного управління, декан факультету управління фінансами та бізнесу Львівського національного університету імені Івана Франка

[2] *Оліскевич Маркіян Мирославович*, Software Developer, компанія ELEKS Software

[3] *Козицький Валерій Андрійович*, кандидат фізико-математичних наук, доцент, доцент кафедри математичної економіки, економетрії, фінансової та страхової математики Львівського національного університету імені Івана Франка