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FORMATION OF AN INNOVATIVE STRATEGY FOR ENSURING THE SOCIO-ECONOMIC SECURITY OF THE STATE

Purpose. To develop proposals for the formation of an innovation strategy to ensure the socio-economic security of the state.

Methodology. Trend analysis made it possible to identify dynamic pattern regularity of the index of Ukraine positioning in the Global Innovation Ranking and the dynamic pattern of the share of losses on scientific research and development in GDP. In order to build scenarios for the implementation of the expenditure portion of the State Budget in terms of financing the areas of the innovation strategy, logical-structural modeling methods were applied. In order to solve the problem of rational distribution of limited financial resources between the areas of the innovation strategy, the Bellman dynamic programming algorithm was used. A systematic approach was used to integrate the financial, organizational and institutional mechanisms of the strategy, including arrangements that do not require budget financing.

Findings. The most significant areas of the innovation strategy and their impact on individual components of the socio-economic security of the state were identified. The use of multipliers as part of a computational model has been substantiated, which affords the opportunity to minimize political distortions in the distribution of financial resources of the state budget, as well as creating a transparent system for effectiveness evaluation of state financial support. Based on the proposed target function, it was featured that the scenario approach should be supplemented with the use of Bellman dynamic programming. It gave an option of solving the problem of optimal distribution of financial resources between different areas of the innovation strategy to maximize the overall effect with limited budget financing. Proposals for the formation of an innovative strategy for ensuring the socio-economic security of the state by integrating scenario analysis, optimal allocation of resources and the implementation of institutional measures with zero budget burden have been developed.

Originality. The methodological approach to the formation of an innovative strategy for ensuring the socio-economic security of the state, which takes into account the distribution of funding between its areas, has received further development. This approach permits optimizing the use of limited resources, including all possible options for evolving the situation in unstable economic conditions.

Practical value. The implementation of Bellman dynamic programming affords the opportunity to increase the effectiveness of the innovative strategy for ensuring the socio-economic security of the state through the redistribution of financial resources. The proposed recommendations provide the opportunity for state bodies to make informed management decisions that ensure the stability of the socio-economic system under conditions of limited funding.

Keywords: *innovation strategy, multiplier, socio-economic security, financing*

Introduction. The formation of an innovation strategy to ensure the socio-economic security of the state is usually based on certain assessments of needs and priorities determined by the government and relevant bodies responsible for the development of innovations. In particular, when planning budget expenditures for the implementation of an innovation strategy, economic conditions, projected results of innovation programs, and the financial potential of the state are taken into account. Thereafter, funding in the sphere of innovation activity is usually distributed between its various areas. However, ensuring certain minimum costs is emphasized for each of the areas without sufficient assessment of the economic effect that these areas can generate, which is a significant error of omission. Aside from that, instead of focusing on long-term economic benefits and the potential of each innovation project, funding is often determined on the basis of short-term assessments or formal criteria. This approach means that more effective and strategically important areas that have the potential to ensure sustainable development and increase the competitiveness of the country may receive insufficient funding. Coincidently, less promising initiatives have the opportunity to receive more resources, which will not ensure the rational use of public funds and will not contribute to strengthening socio-economic security over a long-term horizon.

Hence, it is natural that innovations should not be aimed only at the general development of science and technology, but should be oriented towards solving specific tasks that directly affect the socio-economic security of the state. This is quite obvious in the context of limited state budget resources. Each financed item of expenditure should contribute as effectively as possible to achieving strategic goals in the area of socio-economic security.

Literature review. In the scientific papers by foreign scientists (in particular, Cinar E., Trott P., Simms C., Demircioglu M. [1], Al Hawi T., Alsyouf I. [2]) a distinct commitment towards an interdisciplinary ap-

proach is observed. It combines such methods as case analysis, comparative contextual research, interviewing innovation applicants, analysis of institutional and political background of reforms, as well as formalized typology of innovations according to the country. Such an approach, although of high scientific value, is not entirely suitable for Ukrainian circumstances, since it assumes the availability of a stable institutional environment and political neutrality of innovation implementation processes. Notwithstanding, in Ukraine, the political context is a factor that impacts both the personal composition of innovation implementers and the priorities of its financing. Within this framework, qualitative case analysis or comparison with other countries lose their objectivity, and interviewing officials and analyzing the legacy of reforms will take the form of fixing political turbulence, rather than identifying certain predicted patterns. It is evident that the success of innovation in the public sector depends on flexible management practices that consider the complex socio-economic environment and the time history in it, which is shown in the paper by Brilhante L. and Romero F. [3] and is relevant for Ukraine. That is why domestic research is largely focused on macroeconomic and statistical aspects: analysis of science financing, changes of innovation indices and effectiveness of state programs. Specifically, Kovalchuk V. in his study carries out a deep analysis of trends in the innovative development of the national economy, which allows identifying a number of structural challenges facing the country [4]. This contributes to the formation of the current problem, but the author is limited mainly to descriptive analysis and does not offer a set of tools for resource allocation or an integral mechanism for optimizing their use.

The study by Yatskevych I. addresses the extremely important subject matter of innovation policy in the post-war period, which corresponds to the today circumstances. The author emphasizes the priorities of public administration in the area of innovation [5], but his approach does not provide for a quantitative assessment of the impact of various policy areas on socio-economic security and does not integrate economic and mathematical methods into the process of strategic planning.

Bila I., Posna V. and Shevchenko O. place emphasis on the importance of innovative development as a key factor in the post-war reconstruction of the Ukrainian economy, revealing the potential of technological transformations [6]. The systematic nature of their approach should be recognized, nevertheless, it does not consider the issue of resource limitations, and there is no formalization of strategic decisions over time.

Perminova S., Sytnik H. and Chuprina M. analyze state incentives for innovation activity, which is important for understanding the institutional context of strategy implementation [7]. However, their attention is focused mainly on incentive instruments without attempting to build a model basis for determining the priority of areas of innovation strategy to ensure the socio-economic security of the state. As an alternative, the work by Neustroiev Y. outlines the role of innovation as a factor of economic security, demonstrating the conceptual connection between innovative activity and economic stability [8]. Meantime, despite the profound formulation of the problem, no methodological solutions have been proposed for the formation of an integral strategy that would simultaneously consider resource constraints and institutional arrangements.

Kudlaenko S., Chorna N. and Kelmanovich A. made a valuable attempt to combine the innovation component with regional aspects of socio-economic security, introducing a spacelike dimension into the research [9]. However, the strategic architecture for implementing innovation policy is not supported by algorithmic or optimization solutions, which limits its adaptability to unstable conditions.

The papers by Mishchuk Ie., et al., reflect the interdependence of sustainable innovative development and economic security of enterprises under conditions of instability [10, 11]. However, the proposed approaches have mainly micro-level trends and do not scale to the level of state strategy, which is necessary to solve the set goal of forming a state innovation strategy.

The article by Sukhorukov A. outlines the role of organizational innovations in ensuring economic security within the conditions of global transformations. Consideration of "closing technologies" as an element of risk is a valuable logical complement to the general problem [12]. Concurrently, such threats are not integrated into a single model of resource allocation or risk management of an innovation strategy.

In the paper by Cherep A., Dashko I., Ohrenych Yu., the specifics of forming the concept for ensuring socio-economic security in terms of the use of digital technologies are studied [13]. In addition, scientists analyzed the impact of socio-economic security of enterprises on the economy of the region and the country. The authors Cherep O., Cherep A., Ohrenych Yu., Helman V., Gorbunova A. analyzed the existing types of innovation strategies and improved the mechanism for managing the strategy of innovation activities [14]. For another thing, the authors emphasized the need to develop and implement tools to increase innovation activity using the example of enterprises in the region. Along with this, it is advisable to study and define methodological principles for the formation of an innovative strategy for ensuring socio-economic security at the state level.

Thus, despite the significant contribution of the mentioned scientists to the development of theoretical and applied aspects of innovative development and economic security, most studies ignore the application of formalized methods for forming an innovation strategy in ensuring the socio-economic security of the state. Specifically, approaches are not considered that would be able to ensure the adaptability of the innovation strategy to changing environmental conditions, as well as make possible a rational distribution of limited financial resources between alternative areas of innovation policy, taking into account the multiplier effect. Consequently, considering these omissions is a necessary prerequisite for the further development of a methodological approach to the formation of an innovation strategy in ensuring the socio-economic security of the state.

Unsolved aspects of the problem. The formation of an innovation strategy in the scientific papers of scientists and in the practical sphere is, to a greater extent, focused on supporting innovations as such. In return, attention should be concentrated on supporting specific areas that

will most contribute to the growth of the socio-economic security of the state. Such an approach will allow more effectively forwarding financial resources to achieve its strategic goals, in particular, i.e., creating competitive advantages for the national economy, reducing unemployment, improving the quality of life of citizens and ensure economic stability under conditions of global challenges facing Ukraine.

Despite the existing best practices of scientists, it must be recognized that the methodological problem of forming an innovation strategy for ensuring socio-economic security, taking into consideration the optimal distribution of funding between its areas against the background of resource constraints, has not received due presentation. Although some papers trace certain elements of a formalized approach to strategic planning, though attempts of their systematic application remain fragmentary, and the level of methodological development, in our opinion, is insufficient. Specifically, the application of the Bellman dynamic programming algorithm as a tool that renders possible considering the multiplicity of probable development scenarios, ensuring the adaptability of the strategy to a changing environment and optimizing the use of limited resources based on an target function built taking into account the multiplier effect remains outside the scientific analysis.

The purpose of the article is to develop recommendations for the formation of an innovative strategy for ensuring the socio-economic security of the state.

Methodology. The study used the trend analysis method, which made it possible to track patterns in changes in Ukraine's positioning index in the Global Innovation Ranking and the dynamics of losses related to scientific research and development in the GDP structure. Methods of logical-structural analysis were used to simulate possible scenarios of the implementation of the expenditure part of the State Budget in the context of financing innovation, which made it possible to form reasonable options for the distribution of funds. The Bellman dynamic programming algorithm was implemented, which provides a means of optimizing the distribution of limited financial resources between individual areas of innovative development. Based on the application of a systemic approach, a comprehensive combination of financial, organizational and institutional tools for implementing the strategy was ensured.

Results. Taking into account the research conducted by scientists, we believe that the concept of "innovation strategy of the state" must necessarily consider the purpose associated with ensuring socio-economic security. Still, innovations for the sake of innovations themselves do not have strategic value, and without security purposes they lose specific guidelines and practical focus, passing into fragmentary technological attempts. Concurrently, they must respond to crises and challenges that each state deals with. Therefore, under the innovation strategy of the state, in our opinion, it is appropriate to understand a purposeful system of long-term decisions that determines the priorities and mechanisms for distributing limited resources to stimulate the country's scientific development with the aim of ensuring its socio-economic security. In turn, the concept of "socio-economic security of the state", in our opinion, should take into account the most influential trends of state development and therefore it is advisable to define it as follows: the state's ability to ensure economic modernization, support of infrastructure, science, entrepreneurship and social stability in periods of economic, social, political, military instability.

In order to develop a high-quality innovation strategy for ensuring the socio-economic security of the state, it is advisable to make a well-founded choice of priority areas for funding, compliance with which will guarantee innovative development and stabilization of the socio-economic system. This approach is relevant for Ukraine due to the need for economic recovery based on modern technological solutions.

It is obvious that the financing of scientific research will promote technological breakthroughs and increase the competitiveness of the country. According to OECD research, effective investment in science and innovation plays an important role in achieving economic growth and reducing regional disparities [15]. Nevertheless, in Ukraine, there is a tendency to reduce spending on scientific research and development, which may affect its position in global innovation rankings (Fig. 1).

Based on the data provided on Ukraine's spending on scientific research and development (hereinafter referred to as R&D) as a percentage of GDP and its position in the Global Innovation Index (GII) for the period from 2010 to 2024, there is a clearly defined tendency to reducing funding for science and technology under instability in Ukraine innovation positions. Thuswise, in 2010, R&D spending amounted to 0.83 % of GDP, which is the highest figure for the entire period (data on the value of the GII for this year are not presented). Since 2011, the share of financing has gradually decreased, reaching 0.33 % in 2022–2023, which is almost 2.5 times less than the level in 2010. This decline went hand in hand with fluctuations in Ukraine positions in the GII, namely: with a slight increase in spending in 2018 (0.47 %), Ukraine reached the highest position – it ranked *43rd*. However, in general, even with stable or slightly increasing funding, the country's position in the GII did not always improve. Indicative in this regard is 2013, when spending was almost the same as in 2012, but the position deteriorated from 63 to 71.

The gap between the level of spending and the positions in the ranking is explained by several factors. In particular, the inefficiency of the use of budget funds, the

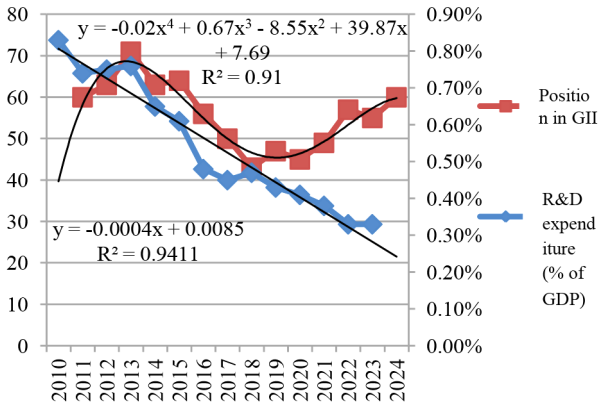

Fig. 1. Changes in the share of research and development expenditures in GDP and the Global Innovation Index in Ukraine [16]

lack of a target innovation policy and poor commercialization of scientific results have led to low innovation performance. However, the structure of the Ukrainian research sector does not comply with the needs of the modern economy, as academic research prevails over the applied or technological developments. Aside from that, political and economic instability, especially since 2014, has significantly affected Ukraine's institutional capacity to attract investment in innovation, which was also presented in its position in the GII. The decline in spending after 2014 was accompanied by attempts to modernize through digitalization, the development of the startup ecosystem, and access to international programs, which partly explains the temporary improvement in the GII rankings in 2016-2018. However, the lack of a comprehensive and stable state policy in the innovation sector, the decline in the level of personnel in science, labor migration, and the low motivation of the private sector to invest in scientific research led to the stagnation of innovation capacity. In 2024, there was a decline to 60th place, which may be the result of a long-term trend of declining investment in R&D, active hostilities, the outflow of intellectual capital, and a general reduction in the functioning of scientific infrastructure.

It is worth mentioning that the changes in Ukraine's ranking in the Global Innovation Ranking are described by a fourth-degree polynomial. Please note that the study used data for 14 years, which provides a statistically justified number of periods sufficient to confirm the reliability of the model as a polynomial of the aforementioned degree. The detected dependence indicates that the domestic innovation changes are the result of the action of complex, often contradictory internal institutional transformation and external economic and political conditions. In addition, it may indicate the absence of a consistent and long-term state policy in the field of innovation.

Based on the results of the study, it is reasonable to acknowledge that without structural reforms, increased investment and effective implementation of an innovation strategy it will be highly doubtful that Ukraine's position in the GII will be improved, even while maintaining the formal level of expenses.

Support for entrepreneurship and startups is precondition by the fact of their flexibility and ability to quickly adapt to market changes. The development of an ecosystem of innovative enterprises through state co-financing, grant programs and preferential taxation creates the prerequisites for increasing productivity, innovation and employment [17].

An important area of innovation policy that can ensure the socio-economic security of the state is infrastructure development. After all, the modernization of transport corridors, digital platforms, energy networks and logistics systems creates the basis for the functioning of other sectors of the economy. The professional literature emphasizes that infrastructure projects have a high fiscal multiplier, which stimulates GDP and employment growth [18]. The basic aspects of infrastructure development as a direction of the state's innovation strategy include:

- introduction of the latest information technologies, in particular broadband Internet, 5G networks, cloud services, the Internet of Things, which allows for effective communication, monitoring and management of various elements of infrastructure (energy networks, transport systems, water supply, etc.);

- development of renewable energy sources, modernization of energy networks using smart technologies to improve energy efficiency, reduce costs and environmental impact. The development of energy-saving technologies and increasing the energy efficiency of buildings and industrial enterprises is also important;

- creation and improvement of transport networks, implementation of intelligent transport systems that are capable of ensuring safe and fast movement of goods and passengers. Innovative solutions should include the development of electric and autonomous vehicles, expansion of the public transport network, as well as improvement of logistics platforms to reduce costs and increase transportation efficiency;

- modernization of healthcare institutions, educational institutions. Innovations in this area should include the use of big data and artificial intelligence to improve the quality of healthcare services, as well as the development of "smart" learning environments with interactive and adaptive technologies to ensure better access to education;

- development of environmentally friendly and sustainable solutions in the field of waste management and natural resource conservation systems, including the introduction of innovative technologies for water and air purification, etc.;

- development of "smart cities", which involve the use of innovative technologies into urban planning, in particular the use of sensors, big data and analytics to improve the urban environment (for example, smart lighting systems, etc.).

Modernization of key sectors of the economy, including industry, energy, agro-industrial complex and transport, takes on particular significance under conditions of war, as the issue of socio-economic security of the state becomes more critical. Armed aggression has led to the destruction of production facilities, logistics chains and energy infrastructure, which has reduced the resilience of the economy and threatens the stability of social processes. Therefore, modernization is not only a tool for economic development, but also a means of adapting to emergency conditions and ensuring the viability of the country.

Modernization of the Ukrainian industrial sector will allow for faster restoration of damaged facilities and the introduction of mobile or decentralized production solutions, reducing vulnerability to attacks. In the energy sector, modernization processes will facilitate the transition to more flexible and distributed supply systems, specifically the development of renewable energy sources, which is most significant under the conditions of the target destruction of energy facilities. The agro-industrial complex, having suffered from land mining, loss of agricultural machinery and disruption of logistics, requires technological updating to quickly respond to changing security conditions, ensure food security and support for rural communities. In the settings of the current state of transport infrastructure in Ukraine, its modernization is the basis for effective evacuation, humanitarian support, military logistics and economic recovery. It will enable the organization of backup routes,

improve mobility for citizens and businesses, and ensure the continuity of domestic and foreign trade even in the event of the usual routes being blocked.

Therefore, as of today, modernization requires the integration of digital and resource-efficient technologies that ensure increased energy security, reduced costs and the implementation of environmentally oriented management [19].

It must be stressed that without a properly developed infrastructure, the modernization of individual sectors of the economy may be complicated. Thus, the development of high technologies requires reliable and fast communication networks and the Internet. Without an effective transport infrastructure (highways, railways, ports), the modernization of industry or the agricultural sector will be significantly limited, and in some cases impossible. Whereas, the development of infrastructure is long-term, basic in nature and requires significant investments in the first stages (construction, modernization). In contrast, the modernization of key sectors of the economy is focused on more rapid changes, which can occur through the introduction of specific technological innovations in certain industries. It is precisely the development of infrastructure that is a prerequisite for economic modernization, which includes the utilization of new infrastructure capabilities, including improved transport systems and energy networks. Therefore, these are two interconnected but different processes.

Social stability and support for the population include innovative approaches to the organization of healthcare, education, digital inclusion, and the social protection system. Innovative technologies in these areas should contribute to reducing social tension, especially in conditions of structural reforms and transitional crises. According to domestic researchers, the digital transformation of public administration and social services ensures increased cost efficiency and strengthening trust in government institutions [20].

The impact of innovation strategy directions on individual components of the state's socio-economic security is summarized in Table 1.

At the same time, the State Budget is an important source of information for developing an innovative strategy to ensure the socio-economic security. It is through it that the amounts of financial resources available to support innovative areas are determined. The selected areas of the innovation strategy for ensuring the socio-economic security of the state in the State Budget of Ukraine are represented by specific budget items responsible for financing these priority areas. Each of them has its own item in the budget, which determines the amount of funding allocated to the implementation of strategic objectives in the relevant areas.

Thus, infrastructure development includes costs for the construction and modernization of roads, bridges, transport infrastructure, as well as investments in energy infrastructure and energy efficiency. Funds for this area are determined through separate infrastructure development programs prepared by the Ministry of Infrastructure of Ukraine. Infrastructure development costs include not only construction costs, but also the costs of technical research, design [21]. The amount of funding for research and development is determined taking into account the needs of scientific institutions, as well as the requirements of international scientific agreements and partnership programs [22].

Support for entrepreneurship and start-ups includes spending on subsidies for small and medium-sized businesses, grants for innovative projects, and funding for programs to develop business incubators and accelerators. In this area, funding is determined taking into account the needs of small and medium-sized businesses and indicators of entrepreneurship development and employment among the population. To this end, cooperation is carried out with local authorities and business associations, which provide information on local needs [23].

The costs of modernizing critical sectors of the economy are determined through state programs and are provided for within the framework of state investment projects and national programs, in particular in the energy sector and infrastructure [24].

Social stability and support for the population is determined by spending on social programs covering pensions, social assistance, and measures aimed at supporting vulnerable groups. The area also includes financing of housing programs, social adaptation of persons with disabilities, unemployment programs and other social payments. Social needs are assessed based on an analysis of the demographic situation, unemployment rate, poverty index, and other social indicators. The Ministry of Social Policy of Ukraine conducts constant monitoring, which serves as the basis for calculating the amount of expenditure for the specified purposes [25].

The methodology for determining the amounts of expenditures for each of these items in the State Budget of Ukraine includes several stages. First, strategic planning takes place through the development of long-term programs in relevant sectors. Ministries and government agencies submit their budget requests based on the analysis of current needs and strategic goals. In particular, for infrastructure development, specific funding amounts are determined for the construction of new facilities and the modernization of existing ones, based on current technical tasks and taking into account national and international requirements. After that, costs are assessed based on forecasts of economic growth, inflation, and other macroeconomic indicators [26].

Furthermore, the amount of funding for research and development is determined on the basis of scientific and technical assessments that take into account global trends and current scientific needs. Similarly, for entrepreneurship and startups, amount of financing is adjusted based on information from business associations and regional administrations. All this data is analyzed by the Ministry of Economy, which, according to these assessments, adjusts funding for entrepreneurial activities [27].

For important sectors of the economy, modernization costs are calculated based on an assessment of the state of infrastructure and the need for its renewal, which is justified following feasibility studies and development programs developed by the relevant ministries. Funding for social stability and population support is determined through an assessment of social needs, including the level of poverty, unemployment and other socio-economic factors, which are analyzed by sociological services and the Ministry of Social Policy.

When calculating the amounts of funding for the areas of the state innovation strategy, it is advisable to take

Table 1

The impact of innovation strategy directions on individual components of the state's socio-economic security

Areas of innovative activities	Financial safety	Information security	Occupational safety	Demographic security	Medical safety	Energy security	Food security	Environmental safety
Infrastructure development	The direct impact is manifested in increased economic efficiency, reduced transportation and logistics costs, and the creation of conditions conducive to attracting investment and business development	Indirect impact through access to modern technologies, reliable communication networks and high-quality data storage systems	Direct impact through new jobs in the infrastructure sector	Direct impact by increasing the level of mobility of the population, promoting an even distribution of resources and labor	Indirect assistance through access to medical services	Direct impact through modernization of energy infrastructure	Direct impact through the development of transport logistics	Direct impact through improved ecological conditions of the transport infrastructure
Support for research and development	Direct impact is reflected through scientific developments that can influence financial stability	Direct impact manifests itself as a means of stimulating the development of new technologies in the field of information security	Direct impact: contributes to the development of a skilled workforce through research programs	Indirect impact through medical and social innovations	Direct impact through medical technologies that can improve the healthcare system	Direct impact through new technologies in renewable energy	Indirect impact through agricultural technologies that support food security	Direct impact through the development of environmentally friendly technologies and environmental research
Support for entrepreneurship and startups	Direct impact through the development of small and medium-sized businesses, which is important for financial stability	Indirect impact: creates conditions for the development of the IT sector	Direct impact through the creation of new jobs in startups and entrepreneurship	Direct impact: increase in the birth rate, improvement of living conditions through support of social initiatives	Direct impact through innovative solutions to improve healthcare services and technologies	Indirect impact through startups and innovations, which helps reduce dependence on imported energy	Direct impact: promotes the development of new agricultural technologies and businesses that improve food security	Direct impact through environmental startups, particularly in the areas of renewable energy and sustainable development

End of Table 1

Modernization of key sectors of the economy	Direct impact due to improved efficiency in important sectors	Indirect impact through industrialization	Direct impact: jobs in strategic sectors of the economy	Direct impact: raises living standards and provides conditions for increasing life expectancy by raising standards in production and housing	Direct impact through the introduction of modern production technologies and process automation, allowing for the production of higher quality medical materials, equipment and medicines, which improves the provision of medical services, increases the safety of treatment and reduces dependence on imports	Direct impact: improves energy Infrastructure and reduces energy risks	Indirect impact on the efficiency of food technologies	Reduces negative environmental impact through modernization of production processes, including emission reduction and energy efficiency
Social stability and support for the population	Indirect impact: can reduce social tensions, leading to economic stability	No direct impact on information security	Direct impact: maintains social status and provides jobs for vulnerable people	Direct impact: improves living conditions, provides support for the poorest segments of the population and helps maintain positive demographic changes	Direct impact: facilitates access to medical services through social programs	No direct impact on energy security	Direct impact: improves access to food resources through social programs	Indirect impact through support of environmentally friendly initiatives and programs for the population

into account both the individual costs for each of the areas identified in the article and their interaction and overall effect on the country's socio-economic security.

To calculate the impact of financing areas of the innovation strategy for ensuring socio-economic security, the use of such a tool as multipliers is envisaged. Their worthwhileness rests upon the fundamental principles of macroeconomic theory, especially, on the idea that state spending has a different effect on gross domestic product, employment levels, innovation activity, and the stability of the socio-economic system [28]. In this case, the multiplier acts as a quantitative indicator of the effectiveness of government spending and is calculated as the ratio of GDP growth to changes in the volume of government spending

$$mg = \frac{\Delta GDP}{\Delta G},$$

where mg is the multiplier of government spending; ΔGDP is the growth of gross domestic product, UAH; ΔG is the growth of government spending, UAH [28, 29].

According to research by experts, the multiplier value for infrastructure investments during periods of crisis can reach 2.0 or even more [28]. According to the European Commission, infrastructure projects demonstrate a multiplier effect within 2.0–2.6, depending on the level of transparency in governance, openness of the labor market, and the state of the institutional environment. Along with this, the costs of supporting scientific research, startups, and entrepreneurship on a short-term horizon have lower multipliers, but provide a high long-term effect, especially in countries such as Ukraine with a dynamic economy [30].

Using a multiplier approach in planning an innovation strategy allows for a transition from the mechanical distribution of financial resources to scientifically based optimization of the cost structure. According to the efficiency formula, the state is able to identify those areas whose funding will provide the greatest impact on the economy and security

$$E_i = m_i \cdot F_i,$$

where E_i is the expected effect of financing the i^{th} area of the innovative strategy for ensuring the socio-economic security of the state, UAH; m_i is the multiplier of the i^{th} area of the innovative strategy for ensuring the socio-economic security of the state; F_i is the amount of financing for the i^{th} direction of the innovative strategy for ensuring the socio-economic security of the state, UAH.

The authors of this article propose the following target function

$$\frac{\sum_{i=1}^{n} E_i \cdot m_i}{\sum_{i=1}^{n} E_i} \to \max,$$

where i is the area of the innovative strategy for ensuring the socio-economic security of the state; n is the number of areas of the innovative strategy for ensuring the socio-economic security of the state; E_i is the effect of implementing the i^{th} area of the innovative strategy for ensuring the socio-economic security of the state; m_i is the value of the multiplier for the i^{th} area of the innovative strategy for ensuring the socio-economic security of the state.

Along with that, it should be pointed out that in a real-life setting, the distribution of budget resources depends on many unpredictable factors, such as changes in the economic situation, political challenges, fluctuations in external markets. Under these conditions, a scenario approach seems logical. It provides a means for taking into account different options for economic development and adjust financing in accordance with changes in external conditions, which provides more flexible and effective management of the state budget. In which, as a rule, certain worst and best options for the development of events are determined. Let us consider the following financing scenarios for the innovative strategy for ensuring the socio-economic security of Ukraine in 2025:

Scenario A – Reduced financing compared to the planned data of the State Budget of Ukraine for 2025, UAH.

Scenario B – Financing in accordance with the values set in the State Budget of Ukraine for 2025, UAH.

Scenario C – Increased financing compared to the planned data of the State Budget of Ukraine for 2025, UAH.

Table 2 presents the financing scenarios for each direction of the innovation strategy and the corresponding values of the objective function.

Therefore, in all the scenarios, there is an increase in the effectiveness of the target function with an increase in funding.

However, the growth rate slows down, which indicates the marginal productivity of financial resources.

Optimization should take into account not only the multiplier, but also the budget constraint, that is, the maximum allowable amount of financing. Aside from this, the scenario approach seems limited due to its static nature. Moreover, the scenarios are created based on assumptions about the future, which may radically differ from real-life environment. Specifically, a decrease in financing in one of the areas may be too pessimistic, and the distribution of financial resources in another scenario may be too optimistic and unrealistic, especially under the conditions of martial law in Ukraine. Such being the case, it is advisable to supplement the scenario approach with the Bellman dynamic programming algorithm. The latter takes into account all the evolution of the situation, applying the principle of optimality, which allows for a more accurate and relevant distribution of resources. Its essence is that the allocation of funding may be presented as a problem in which each area of funding has its own value (in the form of the requested amount) and "utility" (an estimate of the expected effect from financing this area).

Bellman's algorithm makes it possible to sequentially, by filling in the status table, calculate the optimal allocation of funding. Each status is defined as the maximum effect that can be achieved by distributing part of the budget to the first i areas while limiting the expenditure to no more than j (where j varies from 0 to the full budget amounts). The recurrent relationship will be

$$E(i, j) = \max\{E(i-1, j);$$
$$E(i-1, j-c_i) + E_i\}, \text{ under } j \geq c_i,$$

Table 2

Financing scenarios for the areas of the innovation strategy for ensuring the socio-economic security of Ukraine

No.	Innovation strategy area	Multiplier	Scenario A		Scenario B		Scenario C	
			Amount of financing, UAH million	Effect	Amount of financing, UAH million	Effect	Amount of financing, UAH million	Effect
1	Infrastructure development	1.5	2,000.0	3,000.00	2,986.3	4,479.45	4,000.0	6,000.00
2	Support for R&D	2.0	7,000.0	14,000.00	10,154.9	20,309.80	13,000.0	26,000.00
3	Support for entrepreneurship and startups	2.3	14,000.0	32,200.00	18,000.0	41,400.00	22,000.0	50,600.00
4	Modernization of key sectors of the economy	1.8	4,000.0	7,200.00	5,600.0	10,080.00	7,000.0	12,600.00
5	Social stability and support for the population	1.2	150 000.0	180,000.00	175,500.0	210,600.00	200,000.0	240,000.00
6	Total	–	177,000.0	236,400.00	212,240.2	286,869.25	246,000.0	335,200.00
7	Value of the objective function	–	–	1.3350	–	1.3516	–	1.3626

where $E(i, j)$ is the maximum effect that can be achieved when distributing the j^{th} budget amount to the first i areas of the innovative strategy for ensuring the socio-economic security of the state, UAH; j is the amount of the available budget for financing the innovative strategy for ensuring the socio-economic security of the state, UAH; c_i is the amount of financing for the i^{th} area of the innovative strategy for ensuring the socio-economic security of the state, UAH; E_i is the expected effect from financing the i^{th} area of the innovative strategy for ensuring the socio-economic security of the state, UAH.

In the event when the financing of the i^{th} area exceeds the available budget, i.e. $j < c_i$, the formula will look like

$$E(i, j) = E(i - 1, j).$$

At the completion phase of the algorithm, it is possible not only to find the maximum total effect, but also to restore the optimal set of areas that will obtain funding, based on a limited budget. This approach provides an opportunity to build a transparent model for the formation of an innovative strategy, reasonably distributing financial resources following the criteria of efficiency and feasibility.

In the meantime, a number of restrictions should be taken into account. To formalize them in the problem of applying the Bellman algorithm, it is necessary to determine the critical parameters of the dynamic programming problem, in particular, restrictions that ensure the true-to-life and balanced distribution of financial resources. Below is a formalized statement of restrictions with the corresponding economic justification:

1. Restrictions on state budget revenues. Let R be the total amount of state budget revenues in the planning period, which is the upper limit of the available financial resources for financing the innovative strategy

$$\sum_{i=1}^{n} x_i \le R,$$

where x_i is the amount of budget funding allocated to the i^{th} area of the innovation strategy; n is the total number of areas.

2. Limitations on the total amount of state budget expenditures. Since part of the total budget is reserved by fixed (mandatory) expenses, the innovation strategy may be financed only within the share of the total amount of expenses E, which is provided for the development programs

$$\sum_{i=1}^{n} x_i \le E,$$

where $E \le R$, since expenditures cannot exceed revenues unless deficit financing is provided (which can also be simulated, but requires additional assumptions regarding borrowing or reserve funds).

3. Constraints on the minimum required level of financing for each area. Each area of the innovation strategy requires a minimum level of financing mi, without which the effect of the implementation of the area will be zero or will not provide the proper level of security. Thus

$$x_i \ge m_i, \forall \text{ i} \in \{1, 2, ..., n\}.$$

The minimum amounts m_i are threshold values established on the ground of regulatory requirements, strategic priorities, risk assessment results and calculations of the required level of investment to achieve the basic level of functioning of each area. They feature minimum permissible costs to avoid degradation or threats in the relevant segment of socio-economic security.

The final formalization of the restrictions looks like this

$$\begin{cases} \sum_{i=1}^{n} x_з \le \min\left(R, E\right) \\ x_i \ge m_i, \forall i \in \left\{1, 2, ..., n\right\}. \\ x_i \in R+ \end{cases}$$

The established constraints ensure the feasibility of the model and make it possible to apply the Bellman algorithm for a step-by-step solution of the optimal budget allocation problem, taking into account the importance, priority, and minimum critical need of each strategy direction.

Table 3 presents the results of using Bellman dynamic programming.

Consequently, infrastructure development in the budget of Ukraine is represented mainly through the State Road Fund with an estimated funding of UAH

Table 3

Results of using Bellman dynamic programming to determine optimal financing of innovative strategy areas for ensuring socio-economic security

No.	Innovative strategy areas	Multiplier	Base funding, UAH million	Effect	Optimal distribution of financing, UAH million	The effect of optimal distribution
1	Support for entrepreneurship and startups	2.3	18,000.0	41,400.0	60,000.0	138,000.0
2	Support for research and development	2.0	10,154.9	20,309.8	50,000.0	100,000.0
3	Modernization of critical sectors of the economy	1.8	5,600.0	10,080.0	25,000.0	45,000.0
4	Development of infrastructure	1.5	2,986.3	4,479.5	20,000.0	30,000.0
5	Social stability and support for the population	1.2	175,500.0	210,600.0	57,240.2	68,688.2
6	Total	–	212,240.2	286,869.3	212,240.2	381,688.2
7	Value of the target function	–	–	1.3516	–	1.798

43.2 billion, of which UAH 11.3 billion is intended for roads of state importance. The latter amount may be considered as the minimum necessary to maintain critical transport connections. Therefore, the optimization model proposes to increase funding to UAH 20 billion, which will ensure increased efficiency taking into account 1.5 multiplier.

The support for scientific and research work is financed in the amount of UAH 14 billion, which corresponds to approximately 0.7 % of GDP and meets the basic standards. The dynamic programming model determines the optimal amount at UAH 50 billion, which with 2.0 multiplier generates an economic effect of UAH 100 billion and indicates the high potential of science as a tool for economic growth.

The support for entrepreneurship and innovative startups is financed through preferential lending programs "5–7–9 %" (UAH 18 billion) and grant support for small and medium-sized enterprises (SMEs) (UAH 1.4 billion) together – UAH 19.4 billion. The optimized model provides for an increase in the total volume to UAH 60 billion considering the highest 2.3 multiplier, which provides a total effect of UAH 138 billion and indicates the important role of SMEs in increasing the sustainability of the national economy.

Modernization of crucial sectors of the economy by 2025 is mostly financed by external assistance in the amount of UAH 71.8 billion including modernization of industry, transport, housing and utilities and energy. The optimization model suggests a lower level: UAH 25 billion. However, this is due to the fact that the calculations do not take into account dependence on external sources. At the same time, 1.8 multiplier characterizes a significant, although not the highest, economic effect.

Social stability and support for the population is financed within the limits of UAH 419.2 billion, of which UAH 237.9 billion is for pensions, UAH 127.9 billion is for target assistance and UAH 42.3 billion is for subsidies. The dynamic programming model formally determines the effective level at only UAH 57.2 billion with a multiplier of 1.2, but reducing this item is politically and socially unacceptable in the short-term prospects. In this event, the model assessment serves as a guide to potential structural reform in particular through targeting monetization of benefits and optimization of social protection mechanisms. It bears mentioning that in the dynamic programming model, reducing the amount of funding for the social block does not literally mean "not paying pensions or salaries in the budget sector". This is rather a signal that part of the current social spending does not create an economic effect and should be either restructured or redirected to more effective mechanisms for ensuring social protection. Part of social spending may include irrational or risky programs from the point of view of corruption, duplication of functions or redistribution of resources that do not have a multiplier effect on the economy. For example, providing benefits that do not encourage active participation in the labor market or education. In addition, the state may reduce the burden on the budget by involving public-private partnerships in the provision of social services (medicine, education) or by stimulating the development of non-state pension funds and voluntary health insurance. It is noteworthy that already now part of the support for internally displaced persons, low-income people, and people with disabilities is financed at the expense of international organizations (UNDP, UNICEF, World Bank). For the practical implementation of the redistribution of funding from Social Stability and Support of the Population area in favor of innovative and active areas, the following mechanisms for phased implementation with minimizing risks for the most vulnerable population groups seem appropriate:

1. Audit of all social programs, their effectiveness, coverage, outturn costs.

2. Reform of the mechanism for providing social guarantees: from mass to target, from declarative to contractual principles.

3. Launching experimental programs, for example, in specific regions (oblasts) with gradual scaling.

4. Public communication of changes so that the population understands that reduction is not a "cut", but a change in the principle of providing assistance to a fairer and more effective one.

Thus, the optimal distribution of funding within the proposed model allows for an unchanged total resource of UAH 212.24 billion to increase the integrated economic effect from UAH 286.87 billion to UAH 381.69 billion. The value of the objective function (efficiency coefficient) increases from 1.3516 to 1.798, which indicates an increase in the effectiveness of the innovation strategy by almost 33 %.

Underway of implementing the Bellman algorithm, it would make sense to integrate artificial intelligence as

a tool for increasing adaptability, forecasting accuracy and decision-making efficiency in dynamic conditions [31]. Its application will give the opportunity not only to solve the problem of optimal management of financing of the state innovation policy, but also to make it sensitive to a complex system of socio-economic relationships that are difficult to formalize using classical methods. Artificial intelligence, in particular deep learning, can be used to construct an approximation function of the value in the Bellman algorithm under conditions of high dimensionality of the state of space. In this event, it is possible to increase the model's ability to assess the long-term effects of innovative solutions on socio-economic security without a complete search for all possible states. Moreover, AI models can learn from historical data and simulated scenarios revealing latent dependencies between changes in innovation policy and the changes of security indicators (economic sustainability, employment, poverty level, human development index etc.). Moreover, it makes sense to apply machine learning at the stage of scenario generation: instead of the traditional expert method, artificial intelligence analyzes multidimensional trends (global risks, technological shifts, military and political threats etc.) and forms scenarios of environmental development. The latter, in its turn, become input data for a dynamic model. In case of uncertainty, artificial intelligence will allow for flexible model updates based on feedback, enabling adjustments to be made to assessments of situations and the expected consequences of strategic decisions. In this way, an adaptive strategy will be formed that is capable not only of minimizing risks, but also of accumulating innovative potential over the long term, taking into account the scenario horizon.

The innovation strategy should also include a number of measures that do not require direct funding or financial investments, but have significant potential for ensuring the socio-economic security of the state. Such measures include organizational and institutional transformations, regulatory and legal initiatives, as well as actions aimed at revitalizing public administration and internal reserves of society [32].

In order to increase transparency and encourage greater involvement of the scientific community and citizens in the evaluation and monitoring of innovation policy, it is necessary to introduce a system of open access to public administration data in the field of innovation in Ukraine. It is also important to initiate regulatory consolidation of "intellectual audit" procedures in the management structure at all levels, which will ensure the identification of inefficient management practices without additional costs.

A separate area of focus is the implementation of mandatory interagency knowledge and expertise sharing, in particular through formalized quarterly meetings between representatives of science, education, business, and government, which can be organized online at no cost. Strategic measures should also include higher education and professional training of government officers by including relevant topics in existing training programs without increasing their funding.

Aside from that, the formation of a national-level "ideas bank" based on crowdsourcing approaches, in which citizens can submit proposals for solving current problems of socio-economic development free of charge, may be effective. Such an event will not only inspire public participation, but also build an atmosphere of trust and shared responsibility for the future of the state.

Therefore, the formation of an innovative strategy for ensuring the socio-economic security of the state should be based on the integration of methodological principles of scenario analysis, algorithmic means of optimal resource management and implementation of institutional measures with zero budgetary burden. The formation of such a strategy should be viewed as a series of interrelated stages, each of which has its own target function, methodological basis and tools (Fig. 2).

The first step is to analyze the current situation and identify needs. It involves assessing the innovation status of the country, identifying key problems and priority areas that require funding to ensure socio-economic security. On the ground of the data obtained, a set of future scenarios is formed, each of which takes into account different assumptions regarding macroeconomic changes, the geopolitical environment, technological progress and changes in institutional principles.

The second stage involves building scenario-type models in which a plurality of strategic trajectories is implemented. A scenario approach is used here, which allows you to trace the consequences of alternative management decisions in the medium and long term.

The third stage consists of determining the optimal distribution of funding between areas of innovation policy. Bellman's dynamic programming algorithm was applied to formalize the task of optimal distribution of funding between areas of innovation strategy, taking into account budget constraints, expected results, and time delays.

The fourth stage involves the integration of measures that do not require funding, but are able to enhance the effectiveness of the innovation strategy. In particular, they may include, but are not limited to, the introduction of open data procedures, conducting intelligent audits, interdepartmental exchange of expertise, increased citizenry participation through digital platforms, as well as regulatory initiatives that will promote deregulation, decentralization and openness of the innovation environment.

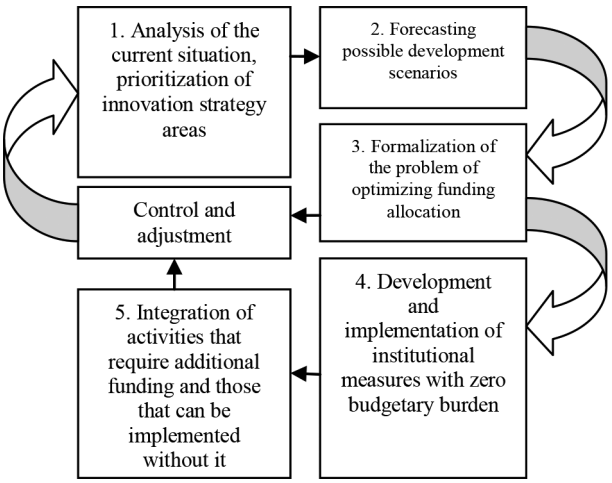

Fig. 2. Sequence of stages in the process of forming an innovative strategy for ensuring the socio-economic security of the state

The fifth stage involves the formalization of a strategic document, which would enshrine the selected development scenario, the financial optimization model according to Bellman, as well as organizational and legal mechanisms for implementing measures without a budget burden.

No less important is the stage of periodic monitoring of the effectiveness of the strategy implementation based on feedback and flexible adjustment of the trajectory in accordance with changes in the external environment.

The strategic plan should provide for the reform of the institutional environment, ensure transparency and stability of funding for scientific institutions, introduce tax incentives for innovation-oriented business, and increase the share of applied research with a clear path to commercialization. All this should be maintained by an increase in the implication of digital technologies, international cooperation, intellectual property, and human capital development.

Conclusions. Thus, the formation of an innovation strategy is based on identifying priority areas of innovation activity that correlate with strengthening the components of socio-economic security, such as financial stability, energy autonomy, labor and demographic potential, ecological balance, information stability. Public funding is viewed through the prism of the multiplier effect, i.e., the ability of individual areas not only to stimulate innovative development but also to maintain the stability of key sectors of the economy and security.

At the macro level, it is worth implementing a comprehensive Bellman dynamic programming model, which will make it possible to optimize the distribution of state funding depending on the expected effect and systemic impact of each area. Alternatively to a universal or proportional distribution of resources, there are good reasons to form an adaptive scenario that includes performance indicators, the speed of innovation implementation, and the potential for partnerships with the private sector.

The formation of an innovative strategy aimed at ensuring the socio-economic security of the state requires a combination of scenario modeling, an effective mechanism for the distribution of financial resources, and a set of cost-neutral administrative and organizational decisions.

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Формування інноваційної стратегії забезпечення соціально-економічної безпеки держави

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Мета. Розробка рекомендацій щодо формування інноваційної стратегії забезпечення соціально-економічної безпеки держави.

Методика. Трендовий аналіз дозволив виявити закономірності динаміки індексу позиціонування України у Глобальному інноваційному рейтингу та динаміки частки втрат на наукові дослідження й розробки у ВВП. Для побудови сценаріїв виконання видаткової частини Державного бюджету у частині фінансування напрямів інноваційної стратегії застосовані методи логіко-структурного моделювання. Для вирішення задачі раціонального розподілу обмежених фінансових ресурсів між напрямами інноваційної стратегії використано алгоритм динамічного програмування Беллмана. Системний підхід використовувався для інтеграції фінансових, організаційних й інституційних механізмів стратегії, включаючи заходи, що не потребують бюджетного фінансування.

Результати. Визначені найбільш значущі напрями інноваційної стратегії та їх вплив на окремі складові соціально-економічної безпеки держави. Обґрунтоване використання мультиплікаторів як частини обчислювальної моделі, що дозволяє мінімізувати політичні спотворення в розподілі фінансових ресурсів державного бюджету, а також створити прозору систему оцінки ефективності державного фінансування. На основі запропонованої цільової функції показано, що сценарний підхід доцільно доповнити використанням динамічного програмування Беллмана. Він дозволив вирішити задачу оптимального розподілу фінансових ресурсів між різними напрямами інноваційної стратегії для максимізації загального ефекту при обмеженому бюджетному фінансуванні. Розроблені пропозиції формування інноваційної стратегії забезпечення соціально-економічної безпеки держави шляхом інтеграції сценарного аналізу, оптимального розподілу ресурсів і реалізації інституційних заходів із нульовим бюджетним навантаженням.

Наукова новизна. Дістав подальшого розвитку методологічний підхід до формування інноваційної стратегії забезпечення соціально-економічної безпеки держави, в якому враховано розподіл фінансування між її напрямами. Такий підхід дозволяє оптимізувати використання обмежених ресурсів, включаючи всі можливі варіанти розвитку ситуації в нестабільних умовах господарювання.

Практична значимість. Реалізація динамічного програмування Беллмана дозволяє підвищити ефективність інноваційної стратегії забезпечення соціально-економічної безпеки держави через перерозподіл фінансових ресурсів. Запропоновані рекомендації надають можливість прийняття державними органами обґрунтованих управлінських рішень, що забезпечують стійкість соціально-економічної системи в умовах обмеженого фінансування.

Ключові слова: *інноваційна стратегія, мультиплікатор, соціально-економічна безпека, фінансування*

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