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FISCAL AND INVESTMENT FACTORS OF UKRAINE’S INNOVATIVE DEVELOPMENT UNDER MARTIAL LAW: A MULTIPLICATIVE MODEL

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ABSTRACT

The relevance of this study is driven by the need to rethink the financing mechanisms for the innovative development of Ukraine's economy under prolonged martial law, as traditional fiscal and investment instruments undergo significant transformations. Analyzing the interaction among budget policy, investment flows, and the institutional environment is crucial to ensuring the resilience of the state's innovation system. The study aims to assess the impact of fiscal and investment factors on innovative development using a multiplicative model of indicators that reflect the correlation between tax burden, investment activity, stock market conditions, and the funding level of research and development (R&D).

In this paper, multiplicative models of the factors influencing the financing of scientific activities in Ukraine were developed, incorporating coefficients for the tax capacity of GDP, investment support of the fiscal system, stock market capitalization of the economy, fiscal mobilization of market capital, and the research and innovation priority of budget funding. R&D expenditure dynamics were investigated across three macroeconomic periods within 2018–2025. For each period, a separate multiplicative model was designed, capturing the pre-crisis state, crisis shock, and wartime economic adaptation phase.

The findings are conceptualized within an integrated model of institutional and resource support for innovative development, illustrating the interaction of institutional, financial, and managerial components of the innovation system. The results confirm a substantial dependence of innovative development on public finance structure, investment activity, and stock market maturity. While wartime conditions reallocate resources to defense, limiting civilian innovation funding, they simultaneously stimulate dual-use technology development. Sustainable innovative development requires combining fiscal incentives, investment activity, and institutional support within the innovation ecosystem. The proposed model enables a comprehensive evaluation of macroeconomic factor impacts on innovation dynamics during periods of high economic turbulence.

Keywords: innovative economic development, fiscal and investment factors stimulating innovation, innovation processes, R&D expenditures, stock market, stock market capitalization of the economy, R&D intensity of GDP, foreign direct investment, state budget expenditures

JEL Classification: E62, C10, O38

INTRODUCTION

In the context of global technological transformations, a national economy's capacity to generate and practically implement innovations becomes a key criterion for its international competitiveness and economic security. In this regard, the innovativeness of an economy indicates its level of advancement, demonstrating a shift away from a commodity-based development model toward a post-industrial society, where intellectual capital serves as the primary driver of value-added creation. It reflects the quality of the domestic institutional environment capable of ensuring a seamless cycle from fundamental scientific discovery to the commercialization of a finished innovative product, which ultimately determines long-term rates of welfare growth and the state's resilience to external crises and threats.

A systemic assessment of the macroeconomic conditions for financing this sphere is particularly important, as innovation processes are inherently characterized by high uncertainty, capital intensity, and long investment payback periods. Without an objective analysis of financial flows, it is impossible to identify structural imbalances that restrict the flow of capital into knowledge-intensive sectors. Within this analytical framework, investigating fiscal and investment factors that sustain the R&D intensity and innovative focus of the economy takes on special significance. Fiscal instruments (tax burden, the structure of public expenditures, the level of tax revenues) determine the state's direct capacity to finance knowledge-intensive economic sectors and act as a guarantor for the development of basic science. At the same time, investment factors, such as the inflow of foreign direct investment and stock market capitalization, reflect the readiness of private and international capital to assume the risks of financing applied research. Analyzing the synergy between these two forces helps determine whether public policy creates the right incentives to attract market resources into the innovation system or, conversely, drains them through inefficient reallocation.

LITERATURE REVIEW

The issues of financial support for innovative activity, and particularly its fiscal and investment stimulation, have been the subject of numerous studies by both Ukrainian and foreign scholars. Today, wartime challenges and the need to develop a post-war reconstruction strategy have intensified research into the economic security of enterprises and the state, especially within the context of their innovative development.

For instance, Horbachenko et al. (2021) examine international approaches to evaluating economic innovativeness through global indices and compare Ukraine's position with other countries. Their findings demonstrate that Ukraine lags behind global leaders in terms of innovative development and requires stronger state support for innovation, an improved regulatory framework, and additional mechanisms to stimulate the growth of innovative businesses.

In their article, Naichuk-Khrushch and Shchur (2023) reveal the significance of financing for the innovative development of enterprises, using the construction industry as an example. They identify the primary sources and success factors of such financing and offer practical recommendations for the effective funding of innovative projects.

Yankovoi (2024) analyzes innovation financing models in Ukraine, their advantages and disadvantages, with particular attention to the role of internal funds, lending, venture capital, government support, and crowdfunding. The author substantiates the need for combining these financing instruments and improving public policy to stimulate innovative development.

Katsydym (2025) emphasizes the need to improve the legal framework for financing innovative development in Ukraine based on international experience, focusing on strengthening credit and tax incentives. The author also justifies the importance of applying innovative approaches to strategic sectors of the domestic economy, particularly within the military-industrial complex.

Gechbaia et al. (2018) take a comprehensive approach to this issue by exploring the theoretical foundations of innovation financing, analyzing European practices in funding innovation, and examining the regulatory framework of this sphere in Ukraine. Based on an analysis of global experience in innovation management within developed countries and leading global corporations, the authors demonstrate the feasibility of using alternative funding sources for innovative activities, tailored to specific stages of the innovation cycle. Additionally, drawing on examples from developed countries, the study outlines directions for state support aimed at innovatively active firms.

A study by Santos et al. (2024) evaluates the impact of different funding sources on innovation at the micro-level. It establishes that different external financing sources yield varying effects: equity capital contributes more to revenue growth, whereas financing linked to fixed asset expansion or liquidity enhancement drives employment growth. The authors argue that a combination of several financial instruments is crucial, pointing to their complementary nature.

Mazzucato and Semieniuk (2017) demonstrate in their study that innovation policy driven by direct public funding can foster radical innovations far more successfully than market-based regulators.

In their article, Bronzini and Piselli (2016) evaluate the impact of an R&D subsidy program in northern Italy on firm innovation. They find that grants significantly increased both the number and probability of patent applications, particularly among small enterprises. To generate one additional application, €206,000–310,000 in funding was required. The causes of and solutions to the innovation funding gap are addressed in a study by Hall and Lerner (2010).

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Contemporary research in the field of innovation is frequently linked to the development of the FinTech ecosystem and digitalization (Jiang et al., 2022; Martinez-Blasco et al., 2025).

Another prominent trend is the study of financing challenges faced by so-called "green" startups (Mukherjee et al., 2024).

In a study by Barman et al. (2022), 23 drivers of financial innovation are identified and classified by the strength and nature of their impact. Technological advancement, competition, firm size, and regulation are identified as the primary factors here.

An OECD study (Berger et al., 2026) analyzes the financing of academic startups (examining 81,318 companies, 8,065 of which were founded by PhDs). The study finds that while these startups are more likely to receive grants, they do not overall attract more funding than other startups. Initial funding sources determine the subsequent trajectory, and transitioning from grants to venture capital proves difficult. The study also highlights the limited role of public venture capital and underscores the need for incubators and accelerators to improve access to investment and enhance the commercialization of innovations.

Contemporary scholars also pay special attention to investigating the factors that influence innovation development. For instance, Atsu and Adams (2023) demonstrate a correlation between a country's financial development and innovation, while also factoring in human capital and institutional quality. At the same time, they find that foreign investment does not contribute to the development of innovative activity. Their study was conducted using the example of 29 OECD countries, with analysis metrics spanning a 40-year period (1980–2019).

A study of 68 developed and developing countries from 1995 to 2018 revealed an ambiguous and non-linear impact of financial development on innovation. While market institutions strengthen this link, the positive effect of credit and stock markets persists only up to a certain level (Trinugroho et al., 2021).

The authors of the next paper (Aslam et al., 2023) took a slightly different approach to analyzing innovation activity by examining the impact of business innovation on firm performance. Their study of 696 manufacturing firms showed that R&D positively affects product, process, marketing, and organizational innovations. It was established that innovation does not depend on firm size, and that older companies carry out R&D more efficiently and deliberately. The significant impact of product and organizational innovations on firm performance was also confirmed.

Authors focusing on bibliometric analysis (Padilla–Ospina et al., 2018) emphasize that the main research areas in the field of innovation include financial constraints, funding sources (both internal and external), venture capital, capital structure, and the financing of technology companies.

A review of literary sources indicates that different funding channels affect small and medium-sized enterprise (SME) innovation in various ways. Traditional sources, particularly bank loans, remain important, while newer instruments–such as crowdfunding and technology bonds–possess significant potential. The research also revealed geographical and sectoral differences in innovation financing, highlighting the need to design tailored financial mechanisms to support SMEs (Alvarez et al., 2025).

An analysis of the development of the innovation sphere in Europe demonstrates the following. The activities of European financial institutions positively influence innovation, increasing the patenting activity of companies through equity financing participation (2007–2019). This effect is enhanced when co-investing with other investors, which confirms their innovation-oriented role in supporting long-term financing, innovation, and economic growth in the EU (Clò et al., 2022).

A study of innovation drivers at the firm level in the EU (2009–2021) (Mitra et al., 2023) proves that larger and more profitable firms innovate more actively, whereas company age reduces innovative activity. It is also shown that the effectiveness of financial instruments depends on the type of innovation (product, process, organizational, or marketing), and that the main challenges for innovative firms are access to finance and regulatory constraints. In this article, we will investigate the factors that determine R&D expenditures in Ukraine during the full-scale invasion, using data from 2021–2024. We will construct a multiplicative model of the impact on this indicator to identify the macroeconomic factors that can help increase spending on the innovative development of the economy.

AIMS AND OBJECTIVES

The purpose of this study is to substantiate a comprehensive structural approach to assessing and stimulating the innovative development of Ukraine's economy under martial law. At the empirical level, the study aims to develop and quantitatively verify a multiplicative model to measure the numerical impact of fiscal and investment factors on R&D expenditure dynamics during both pre-war and wartime periods (using the chain substitution method). At the conceptual level, the study aims to elaborate an integrated model of institutional and resource support, which outlines the qualitative relationships between the budgetary, investment, and institutional parameters that shape the economy's innovative potential.

METHODS

For a comprehensive study, systematization, and generalization of the trends, determinants, and barriers to financial support for the R&D sphere in Ukraine, we applied a set of general scientific methods, including scientific abstraction, theoretical generalization, induction, and deduction. The visualization of the identified macroeconomic trends and the dynamics of the economy's R&D intensity was carried out using tabular and graphical methods, as well as methods of comparison and statistical grouping.

The assessment of the net contribution of individual fiscal and investment levers to the changes in funding volumes for science and innovation was conducted based on a factor analysis of absolute expenditures on research and development (R&D). The chain substitution method, which belongs to the classical elimination methods, was chosen as the mathematical tool for implementing the multi-factor multiplicative model we developed. This approach allows for isolating the effect of each individual factor within a system of interconnected variables by sequentially replacing its baseline value with the reporting value, provided that the values of the remaining variables remain unchanged (fixed). Comparing the results of each subsequent substitution with the previous one enables an accurate quantitative measurement of the vector and scale of the studied factor's impact on the resulting indicator. The core of our mathematical modeling is based on the assumption that the investigated integral indicator (RDE_n) is a function of *n* specific macroeconomic variables linked by a multiplicative relationship:

$$RDE_{n,} = f(I_1, I_{2,}, I_3, I_4, I_5 \ldots I_n) = I_1 \times I_2 \times I_3 \times I_4 \times I_5 \ldots \times I_n.$$

According to the chain substitution methodology, the total variance of the resulting indicator in the reporting period (RDE_1) compared to the baseline period (RDE_0) is determined as:

$$\Delta RDE = RDE_1 - RDE_0 = I_1^1 \times I_2^1 \times I_3^1 \times I_4^1 \times I_5^1 \times \ldots \times I_n^1 - I_1^0 \times I_2^0 \times I_3^0 \times I_4^0 \times I_5^0 \times \ldots \times I_n^0.$$

The calculation of the impact of the first factor (I_1) through the change in its baseline value is carried out as follows:

$$\Delta RDE(I_1) = I_1^1 \times I_2^0 \times I_3^0 \times I_4^0 \times I_5^0 \ldots \times I_n^0 - I_1^0 \times I_2^0 \times I_3^0 \times I_4^0 \times I_5^0 \ldots \times I_n^0 = I_1^1 \times I_2^0 \times I_3^0 \times I_4^0 \times I_5^0 \ldots \times I_n^0 - RDE_0.$$

Calculation of the impact of the second factor I_2:

$$\Delta RDE(I_2) = I_1^1 \times I_2^1 \times I_3^0 \times I_4^0 \times I_5^0 \ldots \times I_n^1 - I_1^1 \times I_2^0 \times I_3^0 \times I_4^0 \times I_5^0 \ldots \times I_n^0.$$

Calculation of the impact of the third factor I_3:

$$\Delta RDE(I_3) = I_1^1 \times I_2^1 \times I_3^1 \times I_4^0 \times I_5^0 \ldots \times I_n^0 - I_1^1 \times I_2^1 \times I_3^0 \times I_4^0 \times I_5^0 \ldots \times I_n^0.$$

Calculation of the impact of the fourth factor I_4:

$$\Delta RDE(I_4) = I_1^1 \times I_2^1 \times I_3^1 \times I_4^1 \times I_5^0 \ldots \times I_n^0 - I_1^1 \times I_2^1 \times I_3^1 \times I_4^0 \times I_5^0 \ldots \times I_n^0.$$

Calculation of the impact of the fifth factor I_5:

$$\Delta RDE(I_5) = I_1^1 \times I_2^1 \times I_3^1 \times I_4^1 \times I_5^1 \ldots \times I_n^0 - I_1^1 \times I_2^1 \times I_3^1 \times I_4^1 \times I_5^0 \ldots \times I_n^0.$$

Calculation of the impact of any given *n*-th factor I_n:

$$\Delta RDE(I_n) = I_1^1 \times I_2^1 \times I_3^1 \times I_4^1 \times I_5^1 \ldots \times I_n^1 - I_1^1 \times I_2^1 \times I_3^1 \times I_4^1 \times I_5^1 \ldots \times I_n^0 = I_1 - \times I_n^1 - I_1^1 \times I_2^1 \times I_3^1 \times I_4^1 \times I_5^1 \ldots \times I_n^0.$$

To verify the accuracy of the performed calculations, we will conduct a mandatory balance check of the factors, according to which the sum of all partial effects must equal the total change in the resulting indicator:

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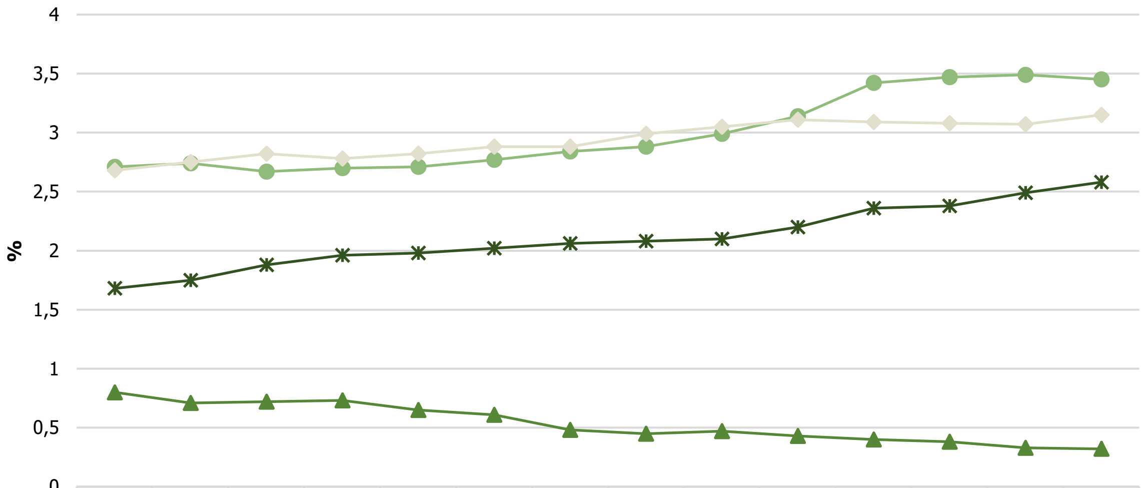
$$\Delta RDE = RDE_1 - RDE_0 = \Delta RDE(I_1) + \Delta RDE(I_2) + \Delta RDE(I_3) + \Delta RDE(I_4) + \Delta RDE(I_5) \ldots + \Delta RDE(I_5).$$

RESULTS

Analyzing the share of R&D expenditures in GDP is a common practice in scientific research. This indicator determines the degree of national economic orientation toward an innovative development model and is recognized as a baseline metric in international practice (specifically under OECD and Eurostat standards) for comparing the R&D intensity of GDP, as it integrates the financial efforts of all macroeconomic system residents (the state budget, business, foreign investors, and the higher education sector) aimed at generating new knowledge. The level of R&D intensity of GDP directly correlates with a country's long-term competitiveness, serving as a measure of its capacity to substitute raw material exports with the production of high-tech goods and services with a high share of value added. Global technological leaders demonstrate a stable increase or maintenance of high R&D intensity levels in their GDP, as shown in Figure 1. China exhibits the most dynamic positive trend, where R&D intensity grew from 1.68% (in 2010) to 2.58% (in 2023), confirming a strategic course toward transitioning to a knowledge-intensive economic model. Unlike global leaders, Ukraine's dynamics reflect a critical trend toward a reduction in the funding of scientific potential. Starting from an unsatisfactory level of 0.8% in 2010, the domestic R&D intensity indicator underwent a consistent decline, reaching an all-time low of 0.32% in 2023 (Figure 1).



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Ukraine	0,8	0,71	0,72	0,73	0,65	0,61	0,48	0,45	0,47	0,43	0,4	0,38	0,33	0,32
USA	2,71	2,74	2,67	2,7	2,71	2,77	2,84	2,88	2,99	3,14	3,42	3,47	3,49	3,45
Germany	2,68	2,75	2,82	2,78	2,82	2,88	2,88	2,99	3,05	3,11	3,09	3,08	3,07	3,15
China	1,68	1,75	1,88	1,96	1,98	2,02	2,06	2,08	2,1	2,2	2,36	2,38	2,49	2,58

Figure 1. Research and development expenditure (% of GDP). *(Source: Eurostat, 2026; World Bank, 2026)*

Such a value is well below the threshold level of economic security and indicates a critical deficit of capital investments in R&D from both the state and the private sector, especially today during Russia's military aggression against Ukraine. At the same time, in this study, we will use the absolute volume of R&D expenditures as the resulting indicator rather than the R&D intensity coefficient, since the absolute indicator more fully reflects the real scale of financial support for research and innovation activities in Ukraine under current conditions.

The R&D intensity coefficient largely depends on the dynamics of GDP itself. Under conditions of economic crises, inflationary fluctuations, or production contractions, as is currently the case for Ukraine, the value of the indicator can change even without a real increase in science funding, which creates a risk of distorting analysis results and complicates the assessment of the actual level of support for the R&D sphere. Furthermore, since most of the indicators applied in the proposed model are relative, it is the absolute resulting indicator that allows for a correct assessment of the quantitative impact of individual factors on changes in research and innovation funding. In addition, because the R&D intensity of the Ukrainian economy is insignificant compared to other countries and consistently remains at a critically low level, this relative coefficient often downplays real structural shifts in the science funding system.

Simultaneously, the growth of R&D expenditures indicates a real expansion of the financial base for building an innovative economy, whereas their reduction signifies critical underfunding of scientific potential, which threatens the degradation of the research sphere and the loss of the state's technological independence in the long term.

To deeply understand the nature of the shifts in the volume of domestic science funding, we will further conduct a factor analysis of research and development (R&D) expenditures using elimination methods, as described above.

Within this study, we will first calculate the total factor impact, followed by a detailed analysis of each specific indicator included in the multiplicative model. The evaluation of individual coefficients will allow us to reveal the internal cause-and-effect relationships between the state's fiscal policy, investment processes, gross product dynamics, and the actual level of financial support for Ukraine's research and innovation sphere.

The period from 2018 to 2025 was selected for the study. This timeframe will allow for a detailed tracking of changes in science funding through the prism of fundamental institutional and security shocks under martial law. For constructing the model of the impact of fiscal and investment factors on the innovative development and innovation processes of Ukraine's economy, it is essential to consider not only the wartime but also the pre-war period. Analyzing the years of full-scale war exclusively does not allow for a full assessment of the nature of the transformations that occurred under the influence of wartime shocks due to the lack of a baseline for comparison. It is precisely the comparison of innovation indicators before and after the start of the full-scale war that makes it possible to identify the scale of structural changes and determine which trends are a consequence of martial law and which were formed earlier. Moreover, this approach also allows for evaluating the resilience of the national innovation system to external shocks.

Within the comprehensive analysis of the dynamics of public expenditures on research and development (R&D) in Ukraine over the 2018–2025 period, three specific years of comparison hold particular analytical value. The selection of these timeframes is driven by their representative significance in assessing the funding resilience of the innovation sector under varying macroeconomic conditions:

2019 relative to 2018 – selected as a baseline period of stable macroeconomic development. This interval characterizes the logic behind the formation and allocation of budget allocations for innovation and the scientific sphere under the steady functioning of the national economy–prior to the global shocks of the COVID-19 pandemic and the onset of full-scale military aggression.

2022 relative to 2021 – reflects a period of unprecedented security and structural shock caused by the start of the full-scale invasion. Studying this cross-section allows for assessing the immediate, primary reaction of the public finance system to military threats, as well as the extent of forced sequestering or reallocation of civilian expenditures in favor of the defense sector, and consequently, the likely reduction in research funding.

2025 relative to 2024 – investigated to evaluate the phase of adaptation and transformation of fiscal policy. Comparing these years makes it possible to determine how well science funding has adjusted to the prolonged conditions of martial law, while also identifying potential trends toward the restoration of knowledge-intensive priorities within the state's long-term resilience strategy.

The omitted periods (2020–2021 and 2023–2024) are merely intermediate adaptation stages, so including them would only obscure the comparison of major structural shifts.

The 2020–2021 period was heavily distorted by quarantine restrictions, declining business activity, and emergency budget reallocations due to the pandemic, which temporarily disrupted standard macroeconomic ratios. Meanwhile, 2023–2024 represents a period of gradual adjustment to the war, when the economy was still searching for new balances and receiving its first large inflows of international aid and grants.

Therefore, selecting these three specific comparison intervals (2019/2018, 2022/2021, and 2025/2024) is entirely sufficient for our study. This allows us to strip away temporary fluctuations and clearly compare three key stages: normal economic performance (2018–2019), the direct shock of the full-scale invasion (2021–2022), and economic performance under martial law (2024–2025).

The proposed multiplicative model is a nine-factor model; the raw data for the calculations are presented in Table 1 (Table 1).

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Table 1. Macro-financial indicators of Ukraine for 2018–2025. *(Source: compiled by the authors based on data from: National Securities and Stock Market Commission of Ukraine, 2026; Portal "Minfin" (n.d.). Statistical data, 2026)*

Indicators	Nominal GDP (at current prices), UAH million	Tax revenues to the State Budget of Ukraine, UAH million	Foreign direct investment in Ukraine, UAH million	Revenues of the State Budget of Ukraine, UAH million	State budget expenditures on economic activity + social protection and social security, UAH million	Stock market capitalization (securities market trading volume), UAH million	Research and development (R&D) expenditures, UAH million
2018	3,558,706	753,815.6	123,358.95	928,108.3	227,466.3	260,870.78	16,773.72
2019	3,974,564	799,776	151,455.216	998,278.9	290,993.7	304,965.7	17,254.63
2020	4,194,102	851,115.6	-23,401.28	1,076,017	491,609.3	335,410.4	17,022.42
2021	5,459,574	1,107,090.9	182,488.23	1,296,853	520,268.8	451,960.6	20,973.78
2022	5,191,028	949,764.4	37,258.3296	1,787,396	521,355.4	160,636	17,117.84
2023	6,537,825	1,203,544.1	155,328.929	2,671,998	603,558.8	436,432.1	21,348.06
2024	7,658,659	1,647,189.6	133,666.341	3,122,713	627,868.2	656,685.3	28,328.17
2025	8,931,194	2,015,818.9	108,475.038	3,834,210	622,159.5	1,076,576	34,653.55

The list of indicators selected as factors driving changes in R&D expenditures and their values for the 2018–2025 period is presented in Table 2.

Table 2. Procedure and calculation results of factor indicators. Note: *At the official NBU exchange rate at the end of the year. *(Source: Calculated by the authors based on data from the State Statistics Service of Ukraine (2026))*

Coefficient	Coefficient Formula	2018	2019	2021	2022	2024	2025
I_1 Coefficient of the tax capacity of GDP	I_1=TRB/GDP *TRB* - Tax revenues of the state budget. UAH million *GDP* - Nominal GDP (at current prices). UAH million	0.211823	0.201224	0.20278	0.182963	0.215075	0.225705
I_2 Coefficient of the relative autonomy (independence) of GDP from foreign investment	I_2=GDP/FDI *GDP* - Nominal GDP (at current prices). UAH million *FDI* - Foreign direct investment in Ukraine. UAH million*	28.84838	26.2425	29.9174	139.3253	57.29684	82.33409
I_3 Coefficient of investment support of the fiscal system	I_3=FDI/TRB *FDI* -Foreign direct investment in Ukraine. UAH million* *TRB* - Tax revenues of the state budget. UAH million	0.163646	0.189372	0.164836	0.039229	0.081148	0.053812
I_4 Coefficient of stock market capitalization of the economy	I_4=SMC/GDP *SMC* - Stock market capitalization (securities market trading volume). UAH million *GDP* - Nominal GDP (at current prices). UAH million	0.073305	0.076729	0.082783	0.030945	0.085744	0.120541
I_5 Coefficient of fiscal mobilization of market capital	I_5=BR/SMC *BR* - State budget revenues. UAH million *SMC* - Stock market capitalization (securities market trading volume). UAH million	3.557732	3.273413	2.869394	11.12699	4.755267	3.561485
I_6 Coefficient of budgetary support for socio-economic development	I_6=BEES/BR *BEES* - State budget expenditures on economic activity and the social sphere. UAH million *BR* - State budget revenues. UAH million	0.24508595	0.291495	0.40117796	0.29168439	0.20106495	0.162265
I_7 Coefficient of research and innovation priority in budget funding	I_7=R&De/BEES *R&De* - R&D expenditures. UAH million *BEES* - State budget expenditures on economic activity and the social sphere. UAH million	0.073741561	0.059296	0.040313353	0.032833342	0.04511802	0.055699
I_8 An indicator of the size of the economy	I_8=GDP *GDP* - Nominal GDP (at current prices). UAH million	3,558,706	3,974,564	5,459,574	5,191,028	7,658,659	8,931,194
RDE	*R&De* - R&D expenditures. UAH million	16,773.72	17,254.63	20,973.78	17,117.84	28,328.17	34,653.55

We have defined the coefficient of the tax capacity of GDP *(I_1=TRB/GDP)* as the first indicator in our multiplicative model. It reflects the level of fiscal extraction of the domestic gross product into the state budget. Through this indicator, we evaluate the intensity of reallocation processes and the actual capacity of the fiscal system to accumulate tax resources relative to the overall scale of national production, in order to finance innovative development from the state budget. This is particularly relevant since public funding serves as the primary driver for innovation abroad (Becker, Roper, Vanin, 2023). The direct link between this coefficient and science expenditures lies in the fact that it determines the state's financial potential. Tax revenues are the main source of funding for the general fund of the state budget, which traditionally finances most domestic research institutions, academic programs, and R&D grants. Consequently, this indicator allows us to trace a fundamental macroeconomic dependence: if the state's ability to collect taxes relative to the scale of the economy grows (due to de-shadowing or optimized administration), the baseline capacity of the budget to finance strategic innovative sectors automatically expands. Conversely, a drop in the tax capacity of GDP narrows the state's options, which, given the fierce competition for budget resources, directly threatens to reduce the absolute volume of expenditures on research and development.

The coefficient of the relative autonomy of GDP from foreign investment *(I_2=GDP/FDI)* was included in the model to assess the relationship between the overall scale of domestic production and the volume of attracted external capital. The interpretation of this indicator requires consideration of the specific characteristics of the analyzed period, which encompasses consecutive crisis episodes: the onset of the COVID-19 pandemic, the shock of the full-scale war, and the subsequent adaptation of the economy to wartime conditions. During this period, foreign direct investment naturally declined substantially due to exceptionally high geopolitical and military risks. Under these conditions of a severe investment shock, the Ukrainian economy largely lost its external investment support, making domestic production the principal compensating factor. By comparing FDI with GDP, we evaluate the extent to which the growth and resilience of domestic production compensated for the loss of external investment resources.

From a mathematical perspective, a reduction in the denominator (FDI) increases the value of the GDP / FDI coefficient, which, within the factor decomposition, generates a positive contribution to the change in R&D expenditures. In the context of the extraordinary period under investigation, this result is interpreted as a positive stabilizing effect, reflecting the increased resilience of the domestic economy and the ability of the macroeconomic system to generate financial resources for science even under conditions of minimal external investment support.

At the same time, this indicator is deliberately retained in the model because foreign direct investment represents not only a source of financial capital but also a major channel for technology transfer, the diffusion of innovation, and the modernization of production. The logical connection between this coefficient and science expenditures is based on the prospective expansion of state tax revenues. Consequently, the inclusion of this coefficient makes it possible to account for the role of technological spillovers and their long-term contribution to the expansion of the tax base through corporate income taxes and personal income taxes (Malynovska Y. et al., 2025), while simultaneously capturing the balance between the country's internal economic resilience and its remaining attractiveness to global technology-oriented investors.

The third indicator in the model is the coefficient of investment support of the fiscal system (*I_3=FDI/TRB)*, which measures the ratio of foreign direct investment to the tax revenues of the state budget. This metric helps assess the level of external investment support relative to the state's internal fiscal capacity, as well as the potential to combine public and private investment resources to fund innovative development. The coefficient allows us to assess the extent to which external investment resources potentially strengthen the state's financial capabilities to finance R&D.

The coefficient of stock market capitalization of the economy *(I_4=SMC/GDP)* and the coefficient of fiscal mobilization of market capital (*I_5=BR/SMC)* allow the model to account for the development level of the national financial sector (I_4) and the nature of the interaction between the state budget system and the securities market (I_5). Both metrics make it possible to evaluate the state of the country's financial market and the government's ability to interact with free entrepreneurial capital in the stock market. The connection of these financial instruments with R&D expenditures is realized through two complementary mechanisms: first, the level of stock market development relative to GDP reflects the maturity of the investment environment. A developed securities market serves as a powerful alternative source of long-term investment for high-tech and knowledge-intensive companies (via the issuance of shares or corporate bonds). The higher the market capitalization, the easier it is for the private sector to attract long-term financing for their own innovative projects, which significantly eases the burden on the state budget. From the perspective of resource mobilization, the coefficient (I_5) helps evaluate the state's capacity to accumulate and reallocate capital circulating in the financial market. Efficient interaction between the budget and the stock market (for instance, through domestic government bonds) allows the state to flexibly maneuver financial resources. Under a balanced policy, this expands the overall liquidity of the budget system, creating additional financial potential for the stable funding of state scientific programs and the support of research infrastructure.

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It should also be noted that the model uses the total volume of securities trading instead of the nominal stock market capitalization. Under current Ukrainian conditions, the conventional capitalization indicator has largely lost its economic relevance due to the severe structural distortion of the stock market. This distortion is manifested in the limited number of operating stock exchanges (only the PFTS Stock Exchange and Perspektyva Stock Exchange remained active in 2025–2026), the overwhelming dominance of government securities (domestic government bonds accounted for approximately 81% of exchange trading, while the share of corporate equities declined to only 0.16% in 2026), and the persistently low market liquidity (National Securities and Stock Market Commission of Ukraine, 2026). Under such circumstances, nominal market capitalization becomes largely a "virtual" measure that does not adequately reflect the actual value of illiquid corporate assets.

By contrast, the volume of securities trading captures only executed transactions and the actual movement of financial resources. Therefore, it provides a more reliable measure of real market activity, avoids methodological distortions associated with nominal capitalization, and ensures greater robustness and reliability of the factor decomposition model.

The coefficient of budgetary support for socio-economic development *(I_6=BEES/BR)* reflects the internal structure and actual direction of public budget policy, showing exactly what share of all accumulated revenues is directed toward investments in human capital and support for the real sector of the economy. Within this fiscal space, the coefficient of research and innovation priority in budget funding *(I_7=R&De/BEES)* measures the internal competitiveness of science by capturing the share of resources that the state purposefully invests in R&D relative to total expenditures on socio-economic development. Nominal GDP *(I_8=GDP)* acts as the closing element. In the structure of the multiplicative model, it serves as a measure of the economic system's scale and reflects its overall financial and monetary capacity. The link between Nominal GDP and R&D expenditures is foundational: the scale of the economy determines the ultimate boundaries of the fiscal space, investment flows, and the overall purchasing power of the state. Furthermore, this indicator integrates the impact of all previous relative coefficients into the final absolute value.

The proposed model reproduces a comprehensive mechanism through which macroeconomic resources are transformed into public financing of innovation activities. The sequence of the coefficients reflects the successive stages of this mechanism. The first group of indicators (I1–I3) characterizes the formation of the fiscal and investment base by combining tax capacity, domestic economic potential, and the role of foreign direct investment. The second group (I4–I5) reflects the level of financial market development and the interaction between the budget system and the capital market, thereby characterizing the availability of alternative sources of innovation financing. The third group (I6–I7) represents the government's budgetary priorities, and the extent to which accumulated financial resources are allocated to socio-economic development and, more specifically, to research and development. The final element of the model is nominal GDP (I8), which serves as a scaling factor that transforms the system of relative coefficients into the resulting absolute value of R&D expenditures.

As a result, the model represents the complete institutional and financial chain underlying public financing of science: financial resource generation → resource mobilization → financial intermediation → budget allocation → research and development financing. The model makes it possible to trace how changes in the fiscal, investment, financial, and budgetary spheres jointly influence the country's innovative development through the mechanism of R&D financing.

Using the chain substitution method, we will calculate the impact of the identified coefficients on R&D expenditures for the 2018–2025 period.

Below are the calculations for the selected years, beginning with 2019 relative to 2018.

$$\begin{aligned}\Delta \mathrm{RDE}\left(\mathrm{I}_{1(2019)}\right) = {} & 0{,}201224 \times 28{,}84838 \times 0{,}163646 \times 0{,}073305 \times 3{,}557732 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ & - 16773{,}72 = -839{,}304\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}\left(\mathrm{I}_{2\,(2019)}\right) = {} & 0{,}201224 \times 26{,}2425 \times 0{,}163646 \times 0{,}073305 \times 3{,}557732 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ & - 0{,}201224 \times 28{,}84838 \times 0{,}163646 \times 0{,}073305 \times 3{,}557732 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ & = -1439{,}36\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}\left(\mathrm{I}_{3\,(2019)}\right) = {} & 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}073305 \times 3{,}557732 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ & - 0{,}201224 \times 26{,}2425 \times 0{,}163646 \times 0{,}073305 \times 3{,}557732 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ & = 2278{,}692\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}\left(\mathrm{I}_{4\,(2019)}\right) = {} & 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}076729 \times 3{,}557732 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ & - 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}073305 \times 3{,}557732 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ & = 783{,}4953\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{5\,(2019)}) &= 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}076729 \times 3{,}273413 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ &- 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}076729 \times 3{,}557732 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ &= -1403{,}1\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{6\,(2019)}) &= 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}076729 \times 3{,}273413 \times 0{,}291495 \times 0{,}073741561 \times 3558706 \\ &- 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}076729 \times 3{,}273413 \times 0{,}24508595 \times 0{,}073741561 \times 3558706 \\ &= 3058{,}921\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{7\,(2019)}) &= 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}076729 \times 3{,}273413 \times 0{,}291495 \times 0{,}059296 \times 3558706 \\ &- 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}076729 \times 3{,}273413 \times 0{,}291495 \times 0{,}073741561 \times 3558706 \\ &= -3763{,}73\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{8\,(2019)}) &= 17254{,}63 - 0{,}201224 \times 26{,}2425 \times 0{,}189372 \times 0{,}076729 \times 3{,}273413 \times 0{,}291495 \times 0{,}059296 \times 3558706 \\ &= 1805{,}298\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE} = 17254{,}63 - 16773{,}72 &= -839{,}304 - 1439{,}36 + 2278{,}692 + 783{,}4953 - 1403{,}1 + 3058{,}921 - 3763{,}73 + 1805{,}298 \\ &= 480{,}91\end{aligned}$$

As can be seen from the model, in 2018–2019, the total volume of R&D expenditures increased by 2.87% (from UAH 16,773.72 to 17,254.63 million), occurring against the backdrop of an 11.69% growth in nominal GDP. The primary positive driver was nominal macroeconomic growth. This was also supported by a slight strengthening of investment support for the financial system through the inflow of foreign direct investment and a minor improvement in stock market performance, which demonstrated a higher level of capitalization relative to GDP. At the same time, the fiscal system exerted a restraining effect on expenditure dynamics: the share of tax revenues in GDP (I_1) decreased slightly, and the coefficient of fiscal mobilization of market resources (I_5) declined due to a reallocation of capital. However, the key destructive factor was a shift in internal budgetary priorities. Despite the fact that the state increased the overall share of funding for socio-economic development (I_6), the coefficient of research and innovation priority (I_7) dropped significantly–from 7.37% to 5.93%. This neutralized the positive effect of GDP growth and locked in a lag in modernization rates relative to the general economic dynamics.

Next, we provide the calculations of the impact of the identified factors on R&D expenditures for the 2021–2022 period.

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{1(2022)}) &= 0{,}182963 \times 29{,}9174 \times 0{,}164836 \times 0{,}082783 \times 2{,}869394 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &- 20\,973{,}8 = -2049{,}84\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{2\,(2022)}) &= 0{,}182963 \times 139{,}3253 \times 0{,}164836 \times 0{,}082783 \times 2{,}869394 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &- 0{,}182963 \times 29{,}9174 \times 0{,}164836 \times 0{,}082783 \times 2{,}869394 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &= 69204{,}82\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{3\,(2022)}) &= 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}082783 \times 2{,}869394 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &- 0{,}182963 \times 139{,}3253 \times 0{,}164836 \times 0{,}082783 \times 2{,}869394 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &= -67155{,}2\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{4\,(2022)}) &= 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}030945 \times 2{,}869394 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &- 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}082783 \times 2{,}869394 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &= -13133{,}5\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{5\,(2022)}) &= 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}030945 \times 11{,}12699 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &- 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}030945 \times 2{,}869394 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &= 22562{,}42\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{6\,(2022)}) &= 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}030945 \times 11{,}12699 \times 0{,}29168439 \times 0{,}040313353 \times 5459574 \\ &- 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}030945 \times 11{,}12699 \times 0{,}40117796 \times 0{,}040313353 \times 5459574 \\ &= -8297{,}8\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{7\,(2022)}) &= 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}030945 \times 11{,}12699 \times 0{,}29168439 \times 0{,}032833342 \times 5459574 \\ &- 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}030945 \times 11{,}12699 \times 0{,}29168439 \times 0{,}040313353 \times 5459574 \\ &= -4101{,}49\end{aligned}$$

$$\begin{aligned}\Delta \mathrm{RDE}(\mathrm{I}_{8\,(2022)}) &= 17\,117{,}84 \\ &- 0{,}182963 \times 139{,}3253 \times 0{,}039229 \times 0{,}030945 \times 11{,}12699 \times 0{,}29168439 \times 0{,}032833342 \times 5459574 \\ &= -885{,}398\end{aligned}$$

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$$\Delta \mathrm{RDE} = 17\,117{,}84 - 20\,973{,}78 = -2049{,}84 + 69204{,}82 - 67155{,}2 - 13133{,}5 + 22562{,}42 - 8297{,}8 - 4101{,}49 - 885{,}398 = -3\,855{,}94$$

In 2022, compared to 2021, as shown by the calculations, the combined impact of the factors led to a reduction in the resulting indicator by UAH 3,855.94 million. The most destructive impact came from the coefficient of investment support of the fiscal system (I_3), whose negative effect amounted to UAH 67,155.2 million. This indicates a significant weakening of the link between investment processes and fiscal mechanisms for economic support. A decline in the level of stock market capitalization of the economy (I_4) also acted as a major restraining factor, reflecting worsening conditions in the capital market and a decrease in investment activity. These destructive processes are linked to the onset of the full-scale invasion along with macroeconomic and security shocks.

Finally, we present the calculations of the changes in 2025 relative to 2024.

$$\Delta \mathrm{RDE}(\mathrm{I}_{1(2025)}) = 0{,}225705 \times 57{,}29684 \times 0{,}081148 \times 0{,}085744 \times 4{,}755267 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 - 28\,328{,}17 = 1400$$

$$\Delta \mathrm{RDE}(\mathrm{I}_{2\,(2025)}) = 0{,}225705 \times 82{,}33409 \times 0{,}081148 \times 0{,}085744 \times 4{,}755267 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 - 0{,}225705 \times 57{,}29684 \times 0{,}081148 \times 0{,}085744 \times 4{,}755267 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 = 12990{,}45$$

$$\Delta \mathrm{RDE}(\mathrm{I}_{3\,(2025)}) = 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}085744 \times 4{,}755267 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 - 0{,}225705 \times 82{,}33409 \times 0{,}081148 \times 0{,}085744 \times 4{,}755267 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 = -14390{,}5$$

$$\Delta \mathrm{RDE}(\mathrm{I}_{4\,(2025)}) = 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}120541 \times 4{,}755267 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 - 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}085744 \times 4{,}755267 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 = 11496{,}28$$

$$\Delta \mathrm{RDE}(\mathrm{I}_{5\,(2025)}) = 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}120541 \times 3{,}561485 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 - 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}120541 \times 4{,}755267 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 = -9997{,}68$$

$$\Delta \mathrm{RDE}(\mathrm{I}_{6\,(2025)}) = 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}120541 \times 3{,}561485 \times 0{,}162265 \times 0{,}04511802 \times 7\,658\,659 - 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}120541 \times 3{,}561485 \times 0{,}20106495 \times 0{,}04511802 \times 7\,658\,659 = -5755{,}68$$

$$\Delta \mathrm{RDE}(\mathrm{I}_{7\,(2025)}) = 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}120541 \times 3{,}561485 \times 0{,}162265 \times 0{,}055699 \times 7\,658\,659 - 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}120541 \times 3{,}561485 \times 0{,}162265 \times 0{,}04511802 \times 7\,658\,659 = 5645{,}004$$

$$\Delta \mathrm{RDE}(\mathrm{I}_{8\,(2025)}) = 8931194 - 0{,}225705 \times 82{,}33409 \times 0{,}053812 \times 0{,}120541 \times 3{,}561485 \times 0{,}162265 \times 0{,}055699 \times 7\,658\,659 = 4937{,}51$$

$$\Delta \mathrm{RDE} = 34653{,}55 - 28\,328{,}17 = 1400 + 12990{,}45 - 14390{,}5 + 11496{,}28 - 9997{,}68 - 5755{,}68 + 5645{,}004 + 4937{,}51 = 6325{,}38$$

The comparison between 2024 and 2025 captures a rather indicative shift: under conditions of limited resources, the state and the economy began to purposefully scale up scientific research. The R&D expenditure (RDE) indicator grew from UAH 28.3 billion to UAH 34.7 billion, and this is not merely an inflationary effect – structural changes are clearly visible here.

The key driver in this case is the growth of the coefficient of research and innovation priority (I_7, from 0.045 to 0.056). This demonstrates that a conscious reallocation occurred within budget policy: science funding is becoming more prominent against the backdrop of general expenditures. Simultaneously, we observe an increase in the stock market capitalization coefficient (I_4, from 0.085 to 0.121). This indicates that innovation began to receive a real "infusion" of capital that was previously less involved in innovative projects – although domestic government bonds (OVDP) certainly predominate here, meaning this indicator is largely tied to the budget and public debt through stock market mechanisms. Conversely, the flip side of this process is a drop in the coefficient of budgetary support for socio-economic development (I_6, from 0.201 to 0.162). This is the logical cost of adaptation: under wartime conditions, budget priorities are rigidly switched from broad social funding to targeted investments in technology and defense capabilities. In other words, the state is forced to sacrifice a portion of social expenditures to fund the knowledge-intensive solutions critical for survival in wartime realities.

In effect, we are witnessing a transition to a model where innovations cease to be an "add-on" to the budget and instead become a tool for survival, which explains the shift in the values of these coefficients.

All results of the factor analysis of R&D expenditures for the 2018–2025 period are presented below (Table 3).

Table 3. Matrix of the factor analysis results of R&D expenditures for the 2021–2024 period.

	2019–2018	2022–2021	2025–2024
I1	-839.304	-2,049.84	1,400.00
I2	-1,439.360	69,204.82	12,990.45
I3	2,278.692	-67,155.20	-14,390.50
I4	783.4953	-13,133.50	11,496.28
I5	-1,403.100	22,562.42	-9,997.68
I6	3,058.921	-8,297.80	-5,755.68
I7	-3,763.730	-4,101.49	5,645.004
I8	1,805.298	-885.398	4,937.51
SUM	480.91	-3,855.94	6,325.38
DELTA	480.91	-3,855.94	6,325.38

The matrix of the factor analysis results of R&D expenditures for 2021–2024 reflects the dynamic nature of R&D spending. Ukraine's financial system has transitioned from inertial stability to conditions of rigorous military adaptation. In the relatively stable period of 2018–2019, the total growth of R&D expenditures by UAH 480.91 million was purely extensive. The primary driver at that time was the natural, nominal growth in the scale of the economy and increased spending on general development, while the internal structure of the budget worked against science–the innovation priority coefficient was falling sharply, demonstrating that the sector was funded on a residual basis.

The onset of the full-scale invasion in 2021–2022 completely broke this trajectory, causing an overall drop in R&D funding by UAH 3,855.94 million. This stage is characterized by a colossal structural shock: internal investment support of the fiscal system practically dropped to zero, and capital critically lost its autonomy, shifting toward external borrowing and financial assistance.

The state was forced to adjust civilian expenditures, which led to a significant reduction in science funding, market activity, and related macro-financial indicators in favor of defense priorities.

In contrast, the 2024–2025 period reflects a phase of fiscal adaptation under martial law, accompanied by an increase in state R&D expenditures of UAH 6,325.38 million. While aggregate macro-financial data do not allow for a precise breakdown of R&D funding by defense, dual-use, or civilian directions, this growth indicates a general expansion of the state's capacity to maintain research activities under prolonged security challenges. Despite martial law, the recovery occurred not only due to the macroeconomic growth of GDP but also as a result of a deliberate shift in state priorities. The key transformation lies in the fact that the research and innovation priority factor entered a confident positive dynamic alongside a substantial increase in stock market capitalization. The budget shifted to a model where funds are withdrawn from general expenses and purposefully concentrated in knowledge-intensive developments, turning innovations from secondary expenditure items into a foundational tool for ensuring the resilience of the state. At the same time, in our view, the innovative development of the economy and innovation processes is determined not only by the financial component but also by other resource provisions and the institutional capacity of the state. To preserve and enhance the innovative focus of the economy, a combination of all components ensuring innovative development is essential. Such a combination can be achieved using the integrated model of institutional and resource support for innovative development proposed in the figure (Figure 2).

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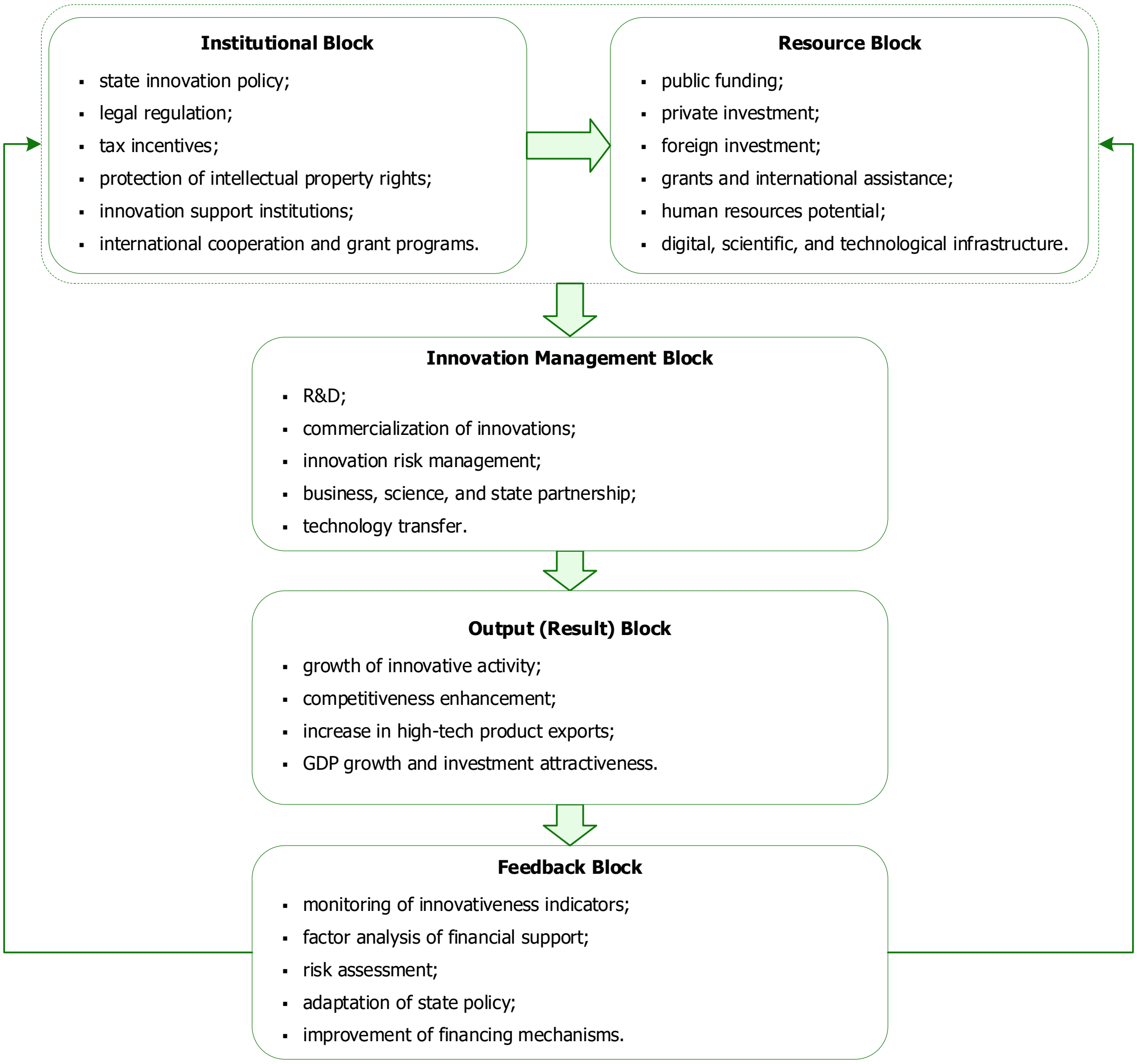

Figure 2. An integrated model of institutional and resource support for innovative development.

The integrated model of institutional and resource support for innovative development is based on the interaction of institutional, financial, and managerial elements that sustain innovative activity. The foundation of the model is formed by the resource block, which reflects the directions of financial, human resource, and technological support for innovation. Its components include public funding, private investment, foreign investment, venture capital, human capital, and digital, scientific, and technological infrastructure.

In contrast, the institutional block–which includes state innovation policy, regulatory framework, tax incentives, mechanisms for protecting intellectual property rights, the activities of innovation support institutions, as well as international cooperation and grant programs–creates a favorable regulatory and organizational environment for developing innovations and attracting investments.

An important role in the model is also played by the innovation management block, which reflects the process of practical innovation implementation through conducting R&D, technology transfer, commercialization of innovations, and cooperation among the state, business, and research institutions. The commercialization of developments is particularly important (Kotvytska & Mazur, 2026). This block ensures the transformation of resources into concrete innovative results.

The output (result) block characterizes the effects of implementing innovative activity, which manifest as increased economic competitiveness, enhanced innovative activity of businesses, development of high-tech production, increased investment attractiveness, and overall economic development.

The final element of this model is the feedback block, which involves monitoring indicators of innovativeness, the efficiency of innovation funding, conducting factor analysis of financial support, assessing risks, and adjusting state policies for innovation support.

It should be noted that the implementation of the integrated model of institutional and resource support for innovative development in Ukraine is accompanied by a number of challenges. One of the key issues is the insufficient level of funding for innovative activity, particularly under the pressure of wartime challenges and limited budgetary resources. Low investment activity in the private sector, the weak development of venture financing, and the limited access of enterprises to long-term lending also remain significant problems.

DISCUSSION

Overall, the obtained results of multiplicative modeling confirm the key thesis of modern innovation development theory regarding the comprehensive nature of the impact of fiscal and financial-investment factors on the innovative activity of an economy. The highlighted factors demonstrate that the availability of financial resources for innovation is largely determined by the quality of institutional support, the efficiency of state regulation, and the level of financial infrastructure development, which is particularly evident during wartime.

The research results align with the findings of domestic scholars regarding the decisive role of financial support for innovative development. In particular, Davydenko, Kliuchka & Kruchko (2024) emphasize that the efficiency of innovative activity heavily depends on the consistency of budget funding and the state's capacity to form long-term incentives for business innovation activity. At the same time, the authors underscore the need to strengthen the role of budget policy in conditions of financial resource constraints, which correlates with the obtained results regarding the importance of public R&D expenditures.

The conducted modeling also confirms the importance of using tax incentives as a tool to revitalize innovative activity. Our conclusions partially align with the research results of Samoilikova (2021), who stresses the need to combine direct and indirect mechanisms of state support for innovation, demonstrating that tax incentives exhibit the highest efficiency when used simultaneously with direct budget funding for research and innovative projects.

Of particular interest are the results regarding the impact of investment factors, specifically the development of the financial market. They correspond with studies on the investment support of innovative development under wartime conditions, which indicate that even under high military risks, investments remain one of the key sources for restoring a country's technological potential. In this context, it is not only the volume of investment resources that becomes crucial, but also their allocation to high-tech and knowledge-intensive sectors of the economy. While a number of authors, such as Bilyk (2018), Khanin (2023), and Maslak & Smirnova (2024), emphasize key factors in shaping the innovative competitiveness of the national economy and the innovative activity of enterprises – such as the investment climate, human capital development, state support for science, international integration, direct financial support for innovation, and the institutional environment – we, in our model, have factored in indicators that reflect stock market development and the degree of autonomy of the macroeconomic system relative to foreign investment, and have proven their significance.

Ayousha Fayyaz & Zoltan Bartha (2025) also identify financial market development and access to capital among the decisive factors for innovative economic development alongside others, which aligns with our research findings.

This study has several limitations that should be considered when interpreting the results.

First, it covers the 2018–2025 period, which was marked by major structural economic changes driven by the COVID-19 pandemic and the full-scale war. Consequently, the findings may be highly specific to a wartime economy, where budget priorities, the structure of public spending, and investment decisions differ fundamentally from peacetime operations.

Second, the model relies on nominal financial indicators during a timeframe characterized by significant inflation and macroeconomic volatility. While nominal values reflect actual fiscal flows, they do not account for purchasing power adjustments or real-term fluctuations in research funding.

Third, the aggregated nature of public budget data imposes constraints on the analysis. Specifically, standard macroeconomic reporting does not allow for a clear separation of R&D expenditures into civilian, defense, or dual-use domains, limiting the ability to draw definitive conclusions regarding sector-specific technology allocations.

Fourth, statistics for the year 2025 remain subject to potential revisions and operational adjustments by official state bodies, which may introduce minor statistical instabilities.

Finally, the selected indicators focus primarily on macro-fiscal and investment factors of innovative development, while other critical determinants—such as human capital dynamics, digital transformation intensity, international technology transfer, and off-budget grant funding—remain outside the structural scope of this factor model. Overall, the research

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results confirm the need to implement a comprehensive state policy to support innovative development, combining budget funding for science, tax incentives for innovative businesses, the attraction of domestic and foreign investments, and the development of the financial sector. In the context of Ukraine's post-war recovery, precisely such a combination of instruments can ensure the formation of a resilient model of innovation-oriented economic growth.

CONCLUSIONS

Integrating the results of the factor analysis of R&D expenditures for 2018–2025 with the concept of institutional and resource support for innovative development allows for clarifying the nature of interaction among financial, institutional, and managerial factors within Ukraine's wartime economy. The obtained results confirm that the dynamics of research and development funding are directly dependent on the state of the budget system, investment flows, the stock market, and the innovative orientation of state policy. During the wartime period, this interaction acquires specific characteristics, as a significant portion of resources is reallocated for defense needs, which simultaneously creates both constraints and new incentives for the development of defense and technological innovations.

The evolution of the factor matrix across the three historical cross-sections illustrates a radical shift in the philosophy of capital reallocation in Ukraine. The transformation of the factor matrix structure across the three defined chronological intervals demonstrates a fundamental change in the nature of the fiscal reallocation of financial resources under the influence of exogenous security shocks.

An analysis of the 2018–2019 interval indicates the presence of an extensive development model in the innovation sector. During this period, the growth of R&D expenditures was ensured in an inertial manner due to positive macroeconomic dynamics and the nominal expansion of the scale of the gross domestic product. At the same time, structural factors within the budget system exerted a destructive impact, as the coefficient of research and innovation priority in public allocations decreased significantly, locking in the funding of science on a residual basis.

The 2021–2022 period is characterized by deep structural disruption and a decline in the resulting indicator under the influence of an unprecedented military shock. The factor matrix captures a critical drop in the autonomy of national capital and its direct dependence on external funding sources, accompanied by an actual shutdown of internal investment support. The prioritization of the defense sector led to a rigid sequestration of civilian programs, resulting in a substantial reduction in public expenditures on general socio-economic development, market capitalization, and scientific infrastructure.

In contrast, the 2024–2025 timeframe reflects a qualitatively new stage–a transition to a model of intensive military-technological adaptation. The obtained results confirm the provisions of institutional-resource theory regarding the dominant role of the state in managing innovation processes during crises. The positive growth in R&D funding in 2025 was secured not only by the macroeconomic stabilization of GDP but also by a purposeful restructuring of the expenditure side of the budget. A pragmatic contraction of general expenditures on socio-economic development took place to accumulate capital in knowledge-intensive defense developments, which led to a rapid increase in the coefficients of innovation priority and stock market capitalization of the economy.

In view of this, ensuring the long-term resilience of the national innovation system requires the further implementation of a comprehensive state strategy based on the harmonization of institutional incentives, the development of the financial environment, and deeper integration into the global scientific and technological space.

The ongoing war substantially transforms the core of innovation policy, shifting its focus toward defense technologies. In this context, the institutional block of the model gains particular importance, as it is state policy, fiscal incentives, and international financial support that determine the possibilities for funding R&D. At the same time, the results of the factor analysis confirm that without developing the investment and market environment (specifically the stock market), sustainable growth in innovative activity remains limited. Implementing the proposed directions of state support – ranging from R&D funding to the development of innovation infrastructure and international integration – is critically important for shaping a resilient innovative development model and enhancing the economic and technological resilience of the state in the face of prolonged security challenges.

Future research should look to expand the proposed model by incorporating these institutional, technological, and socio-economic factors that shape a country’s innovation capacity. Promising directions include integrating indicators for human capital development, public governance efficiency, business innovation activity, venture capital, international technical assistance, and Ukraine’s integration into the European economic space. Additionally, comparative studies between Ukraine and other countries, particularly in Central and Eastern Europe that share similar institutional features or post-crisis recovery experience, would be of significant academic value. This would help evaluate the universality of our approach and identify how fiscal and investment mechanisms for innovation support function across different economic environments.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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ФІСКАЛЬНІ ТА ІНВЕСТИЦІЙНІ ЧИННИКИ ІННОВАЦІЙНОГО РОЗВИТКУ УКРАЇНИ В УМОВАХ ВОЄННОГО СТАНУ: МУЛЬТИПЛІКАТИВНА МОДЕЛЬ

Актуальність дослідження зумовлена необхідністю переосмислення механізмів фінансування інноваційного розвитку економіки України в умовах тривалого воєнного стану, коли традиційні фіскальні та інвестиційні інструменти зазнають суттєвих трансформацій. Особливої значущості набуває аналіз взаємодії бюджетної політики, інвестиційних потоків та інституційного середовища в забезпеченні стійкості інноваційної системи держави. Метою дослідження є оцінка впливу фіскально-інвестиційних чинників на інноваційний розвиток економіки України на основі мультиплікативної моделі індикаторів, що відображають взаємозв'язок між податковим навантаженням, інвестиційною активністю, станом фондового ринку та рівнем фінансування науково-дослідних і дослідно-конструкторських робіт.

У роботі побудовано мультиплікативні моделі впливу на фінансування наукової діяльності в Україні, які включають коефіцієнти податкової місткості ВВП, інвестиційної підтримки фіскальної системи, фондової капіталізації економіки, бюджетної мобілізації ринкового капіталу та науково-інноваційної пріоритетності бюджетного фінансування. Досліджено динаміку видатків на НДДКР у розрізі трьох макроекономічних періодів упродовж 2018-2025 років, для кожного з яких побудовано окрему мультиплікативну модель, що відображає докризовий стан, кризовий шок та етап адаптації економіки в умовах війни. Отримані результати дослідження концептуалізовано в межах інтегрованої моделі інституційно-ресурсного забезпечення інноваційного розвитку, яка відображає взаємодію інституційних, фінансових та управлінських складових інноваційної системи.

Результати дослідження підтвердили істотну залежність інноваційного розвитку від структури державних фінансів, інвестиційної активності й рівня розвитку фондового ринку. Виявлено, що воєнні умови спричиняють перерозподіл ресурсів на користь оборонного сектора, що обмежує фінансування цивільних інновацій, але водночас стимулює розвиток інноваційних технологій подвійного призначення. Сталий інноваційний розвиток можливий лише за умови поєднання фіскальних стимулів, інвестиційної активності й інституційної підтримки інноваційної екосистеми. Запропонована модель дозволяє комплексно оцінювати вплив макроекономічних факторів на інноваційну динаміку в умовах високої турбулентності економіки.

Ключові слова: інноваційний розвиток економіки, фіскально-інвестиційні чинники стимулювання інновацій, інноваційні процеси, видатки на НДДКР, фондовий ринок, фондова капіталізація економіки, наукомісткість ВВП, прямі іноземні інвестиції, видатки державного бюджету

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