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Svitlana Tkalenko
D.Sc. in Economics, Professor of the Department of European Economy and Business, Kyiv National Economic University named after Vadym Hetman, Kyiv, Ukraine;
e-mail: sv.tkalenko@gmail.com
ORCID: 0000-0003-0385-846X
(Corresponding author)

Zhanna Derii
D.Sc. in Economics, Professor of the Department of Economics, Accounting and Taxation, Chernihiv Polytechnic National University, Chernihiv, Ukraine;
ORCID: 0000-0003-3695-7202

Maksym Koriavets
PhD Student, Department of Economics, Accounting and Taxation, Chernihiv Polytechnic National University, Chernihiv, Ukraine;
ORCID: 0009-0004-1298-4227

Maksym Polyanskyy
PhD Student, Department of Economics, Accounting and Taxation, Chernihiv Polytechnic National University, Chernihiv, Ukraine;
ORCID: 0009-0002-9425-2817

Roman Danylevskyi
PhD Student, Department of Economics, Accounting and Taxation, Chernihiv Polytechnic National University, Chernihiv, Ukraine;
ORCID: 0009-0007-2022-3155

Pavlo Detsiuk
PhD Student, Department of Economics, Accounting and Taxation, Chernihiv Polytechnic National University, Chernihiv, Ukraine;
ORCID: 0009-0004-7192-3811

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INNOVATIVE AND INVESTMENT MODEL OF STATE DEVELOPMENT AS A FACTOR OF ECONOMIC GROWTH IN THE POST-WAR PERIOD OF UKRAINE

ABSTRACT

The article examines current issues of innovation and investment development of the state, using Ukraine in the post-war period as a case study. The authors focus on the fact that innovation- and investment-driven development is a key driving force of post-war reconstruction and a necessary prerequisite for economic growth. The post-war reconstruction strategy provides an opportunity for a leap toward a qualitatively new development model, which requires direct investment and advanced technologies.

In the study, the authors emphasize quantitative innovation and investment indicators such as R&D expenditures, the number of innovation-active enterprises, and foreign direct investment. The hypothesis is tested that innovation and investment development in Ukraine have a positive effect on GDP growth. The main indicators of Ukraine's innovation and investment development are analyzed, and it is determined that even under wartime conditions, Ukraine demonstrates strong internal innovation potential; however, the existing investment model does not ensure full-scale technological development.

The authors conclude that an increase in R&D expenditures will have a systemic and long-term positive effect, manifested not only in GDP growth, but also in the formation of an innovation-oriented economy and an increase in the share of value added in production. Increasing R&D expenditures can become one of the most powerful drivers of Ukraine's economic growth and technological breakthrough.

The study is useful for government agencies developing strategies to attract foreign investment in the post-war period and for the private sector seeking to further develop its business.

The study applies the principles of a systemic approach in analyzing the impact of innovation and investment development indicators on economic growth in the post-war period, the principle of reliability, which reflects the current state of national economic development, as well as the principles of information accessibility and representativeness to ensure the validity of the research results.

Keywords: innovation and investment development, post-war reconstruction, economic growth, innovative technologies, foreign direct investment, European integration, digitalization, green technologies, modernization

JEL Classification: O31, E22, F21

INTRODUCTION

Innovative and investment-driven development is a key driving force behind the rapid, sustainable, and high-performance post-war reconstruction. If targeted R&D financing, FDI incentives with localization, human-capital development, and a transparent institutional framework are combined, Ukraine can transform the reconstruction process into a long-term period of competitive economic growth.

The relevance of this issue is determined by the strategic necessity for Ukraine to transition to sustainable, intensive, and high-quality economic growth based on a new technological foundation after the end of the war. According to preliminary estimates by the Ministry of Economy, Environment, and Agriculture of Ukraine, in 2025, Ukraine's real GDP grew by 2.2% (Ministry of Economy of Ukraine, 2025). The growth was due to the implementation of the recovery and business development program (financed by international financial assistance), due to increased household consumption, and budget expenditures for the restoration of critical infrastructure. According to EBRD estimates, Ukraine's real GDP could grow by 2.5% in 2026, and in 2027, assuming the war ends, the economy could accelerate growth to 4% (EBRD, 2026). The World Bank's forecast for 2026 is economic growth at 2% (World Bank, 2025). The NBU has also downgraded its previous forecast for Ukraine's real GDP growth for 2026 from 2% to 1.8%. Thus, the current stage of economic growth is still low, and fiscal support is key. There is a pressing problem - to promote economic growth, while the war continues and the losses increase.

The war and the ongoing security uncertainty have also affected the investment climate. Foreign direct investment remains low, although it shows some signs of stabilization. Innovative activity retains potential, but its development is also constrained by high risks and instability. According to forecasts by international organizations, FDI inflows remain low. Thus, to accelerate economic growth, a peaceful resolution of the conflict is first and foremost necessary, which is a key factor in improving long-term prospects and further reconstruction of the state.

Post-war reconstruction turns the challenge of economic recovery from an urgent need into a strategic opportunity for a leap toward a qualitatively new development model. In this context, innovation- and investment-driven policy becomes a key transformation mechanism that determines not only the speed of restoring production capacities and infrastructure, but also the long-term competitiveness of the economy, the level of added value, employment, and resilience to future shocks.

Direct investment during reconstruction has unique potential for technology and knowledge transfer; at the same time, there are significant risks of inefficient resource use, corruption, and economic dependency. Scientifically grounded modeling of the interaction between investment flows and domestic innovation capacity is required to maximize the multiplier and long-term effects.

In the context of European integration, Ukraine must seize the opportunity to attract foreign direct investment and advanced technologies for sustainable economic growth. A simple restoration of pre-war production levels and infrastructure is insufficient and does not meet the country's European integration ambitions. High-quality post-war recovery should be built on the principles of energy efficiency, green technologies, and digitalization. It is the innovation- and investment-driven model that serves as the key to Ukraine's successful integration into the European Union.

LITERATURE REVIEW

The issue of innovation and investment development is relevant for countries aiming for sustainable economic growth; for Ukraine, this topic is especially important in the context of post-war recovery. Various aspects of innovation and investment development are explored in the scientific research of both domestic and foreign scholars.

In the study by M. Berdar et al., innovation and investment development are presented as key factors influencing the development of enterprises and, consequently, the economy and economic growth in the post-war period (Berdar et al., 2024). The authors focus on investments in innovation, identify challenges for businesses, and prospects for recovery and development after the end of a full-scale war.

The work of I. Markina examines the characteristics of innovation and investment policy for economic growth based on the experience of industrially developed countries (Markina & Marchyshynets, 2019). In their study, E. Limonova and A. Mandic describe innovation as a factor of economic development, technological leadership, and economic competitiveness, as well as investment as a driver of innovation (Limonova & Mandic, 2020).

Trends in innovation activity in the context of sustainable development and economic growth are presented in the work of V. Dyachenko et al. (Dyachenko et al., 2022). The authors outline Ukraine's position in international innovation rankings, compare R&D expenditures in Ukraine and other countries, and conclude that for post-war recovery, Ukraine must promote the integration of economic transnationalization processes with innovation activity, which is a key factor in international economic cooperation (Dyachenko et al., 2022, p.40).

A. Cherep et al. focus in their article on the relationship between investment development and innovation activity of Ukrainian industrial enterprises (Cherep et al., 2021). They examine the investment climate and propose an algorithm-

based model for the development of innovation activity in industrial enterprises, which helps determine the most effective ways of allocating investment resources.

Using the example of companies in the United Kingdom, researchers D. Audretsch et al. examine the relationship between investments involved in the search, development, and implementation of innovations (Audretsch, Belitski, & Chowdhury, 2024). The authors investigate how companies utilize knowledge investments to shape their innovation strategies and generate new ideas.

Foreign direct investment in the economic sectors of host countries, along with technology transfer as well as potential risks and harmful threats to the host country's growth and welfare, are explored in the fundamental study by Theodore H. Moran (Moran, 2012).

The relationship between FDI and the productivity of national firms in the host country is examined in the work of C. Newman et al. (Newman et al., 2015). The positive impact of FDI in the host country on GDP (economic growth) is emphasized and analyzed in the study by K. Saggi (Saggi, 2002).

In the context of the war in Ukraine, the experience of countries that restored their economies deserves attention, for example, the programs for the restoration of the Balkan countries after the war in the 1990s. Thus, in the work of V. Postolovsky, the key role of the EU in the post-war restoration of countries after the devastating consequences of the 1990s is shown; the losses from the war and the impact of the European integration perspective on the internal transformations of these countries are assessed (Postolovsky, 2025). The article by the authors S. Schultz et al. substantiates the structural transformations of the economies of Bosnia, Croatia, and Serbia after the conflict, analyzes the directions of restoration, including the modernization of sectors, support for entrepreneurship, and macroeconomic policy (Schultz, 2023). V. Gramotnev reveals the effectiveness of the policy of attracting FDI during the reconstruction period after the conflicts of the 1990s and their impact on economic growth (Gramotnev, 2025). Also, a number of other foreign authors, such as A. Branković and S. Sarajčić (Brankovic & Sarajčić, 2024), S. Brans et al. (Brans et al, 2013), F. Taskovski (Taskovski, 2023), etc., reveal in their works the impact of FDI on economic growth in the context of post-war recovery.

Modern concepts, in particular sustainable development, are revealed in studies by international organizations (WB, OECD, etc.), which envisage a combination of economic growth with social integration and environmental responsibility. It is important for Ukraine that investments are directed not only to GDP growth, but also to the restoration of territories, support for SMEs, job creation, and environmental modernization. The war demonstrated the critical importance of technological autonomy, the need to develop the processing industry and the military-technological sector; therefore, the concept of technological modernization can become a driver of growth. Post-war recovery can be carried out immediately on the basis of "green" technologies, which will increase the competitiveness of the economy. By directing the FDI into decarbonization, energy efficiency, renewable energy, and clean transport, the concept of green transformation is implemented (Derii, 2024; Tkalenko, 2024). Therefore, the integration of these concepts will allow us to form an investment and innovation model for the development of Ukraine, capable of promoting post-war reconstruction, ensuring long-term growth, technological modernization, and integration into the European economic space.

Previous research by the authors has also focused on the impact of FDI on GDP growth, though without analyzing innovation strategies or policy (Tkalenko et al., 2021). Therefore, the search for optimal pathways to sustainable economic growth in the post-war period has sparked the authors' interest and determined the relevance of conducting this study, developing a model, and forecasting innovation- and investment-driven economic development as a growth factor.

AIMS AND OBJECTIVES

The purpose of the article is to assess the impact of innovation and investment development on Ukraine's economic growth in the post-war period and to substantiate its priority role in the post-war recovery strategy.

Based on the stated purpose, the main objectives of the study are to:

- assess the current state of Ukraine's innovation and investment development under wartime conditions and during post-war recovery on the basis of key quantitative indicators;
- analyze the functional links between economic growth and indicators of innovation and investment development, to develop and empirically verify an econometric model assessing the influence of innovation and investment determinants on economic growth, to identify causal interdependencies, and to conduct predictive assessments;
- substantiate practical recommendations for improving the effectiveness of the innovation and investment development model of the state in the context of post-war recovery and European integration.

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METHODS

The authors used the method of theoretical generalization and system analysis to identify the relationships between investments, innovations, and economic growth and to form the conceptual structure of the study; structural and functional analysis was used to determine the role of investments and innovations in the post-war recovery and economic growth of Ukraine; multivariate regression modeling based on the use of E-Views allowed us to determine the strength and direction of the relationship between the selected model data and to carry out scenario modeling of the economic growth forecast until 2028.

To model Ukraine's innovation and investment development, one of the strategic directions of future progress and post-war recovery, we use the E-Views software, which makes it possible to forecast and analyze various development scenarios. This software is relevant given the objectives of the present study. The multifactor regression model takes the form:

$$Y = f(X1 \ldots Xn), \quad (1)$$

The constructed model will be tested for the significance of the variables, their impact on economic growth (Y), and the strength of the relationships among the selected variables. Based on the influence of the chosen factors on economic growth, the econometric model enables us to draw conclusions regarding the country's innovation and investment development.

It should be noted that many scientific publications, both foreign and domestic, consider these variables. Thus, in our previous pre-war studies, the features of Ukraine's investment and innovation development and its impact on economic growth were revealed (Tkalenko, 2021); the study by J. Dempere et al., the impact of innovations (measured through the Global Innovation Index) on GDP per capita, FDI, and innovation activity in many countries of the world is investigated, where has been established a positive relationship between innovation and economic growth (Dempere, 2023); in the empirical study by J. Chen and Z. Zhou, it is shown that FDI stimulates innovative entrepreneurship and its growth, which is an intermediate mechanism for long-term economic growth (Chen & Zhou, 2023); the analysis of the impact of FDI on economic growth in the first two years of the war is studied in the work of A. Stavytskyy et al. (Stavytskyy, 2025).

So, after analyzing many literary sources and using E-Views to confirm the significance of variables in the current conditions of the development of the Ukrainian economy, we selected the following indicators: the number of innovatively active enterprises, the number of introduced types of innovative products, and FDI.

Statistical data for the analysis cover the period 2010–2024, giving the model 15 observations. The general form of the model is described by the equation:

$$GDP = f(RDE, Q, K, FDI) \quad (2)$$

where, RDE – expenditures on R&D, USD million; Q – number of innovation-active enterprises, million units; K – number of implemented types of innovative products, million units; FDI – foreign direct investment in Ukraine, USD million (liabilities according to the international investment position); GDP – gross domestic product, USD million.

In selecting the most relevant factors, the study is guided by the principle of reliability, ensuring an accurate representation of Ukraine's innovation and investment development in the context of wartime challenges, as well as the principle of data accessibility, which entails the use of official statistical information provided by state authorities; and the principle of representativeness, ensuring that each selected variable is essential and well-justified. Quantitative factors were chosen for the modeling, although qualitative factors, such as anti-corruption efforts, are also highly important.

The hypothesis is that innovation and investment development in Ukraine in modern conditions and in the conditions of post-war recovery have a positive impact on economic growth and an increase in the country's GDP. Therefore, at the current stage, economic growth depends on the innovative activity of economic entities and investment inflows, since domestic investment is insufficient. We assume that increased expenditures on R&D (RDE), expansion of the range of implemented innovative products (K), growth in the number of innovation-active enterprises (Q), and an increase in foreign direct investment (FDI) contribute to the rise of gross domestic product (GDP). Thus, these factors are expected to have a positive and statistically significant impact on economic development.

Trends in Ukraine's Innovation and Investment Development

Currently, studies by Ukrainian scholars have begun to emerge that focus on the specifics of the innovation and investment mechanism in the context of reconstruction after wartime destruction, taking into account short-term shocks, capital shortages, and the need for rapid large-scale investment. Before the war, academic research was primarily focused on the general role of innovation in economic growth or the impact of FDI on economic growth. The main indicators of innovation and investment development are presented in Table 1.

Table 1. Selected indicators of innovation and investment development of Ukraine. *(Source: Global Innovation Index, WIPO, NBU, UNDP, State Statistics Service of Ukraine)*

Year	FDI, USD million	Number of innovation-active enterprises, units	Number of implemented types of innovative products, units	R&D expenditures, USD million	Human Development Index	Global Innovation Index, country ranking
2010	57985	1800	2408	10.2	0.782	61
2011	66304	1800	3238	10.7	0.787	60
2012	75034	1758	3403	11.8	0.789	63
2013	7888	1715	3138	12.88	0.794	71
2014	63910	1609	3661	7.98	0.788	63
2015	48694	824	3136	5.1	0.788	64
2016	50426	8173	4139	4.5	0.78	56
2017	50459	8173	2387	5.1	0.785	50
2018	49829	2283	3843	6.58	0.784	43
2019	56810	2283	2148	6.7	0.789	47
2020	55142	26904	4066	8.7	0.783	45
2021	69926	26904	1756	8.4	0.772	49
2022	54691	24688	2347	4.7	0.772	57
2023	59987	24688	2715	3.6	0.779	55
2024	59953	23564	3397	6.9	no data	60

The analysis of the statistical data in Table 1 showed:

1. First, until 2014 (annexation of the territory of Crimea, the war in Donbas, and the economic crisis), FDI was increasing due to stable economic growth and market attractiveness. Although FDI volumes were small compared to other countries, Ukraine remained an attractive destination (Tkalenko et al., 2021). After 2014, a decline is observed; during 2015-2021, there is relative stability without major breakthroughs, indicating low investment attractiveness and weak structural reforms. Since 2022, Ukraine has been receiving financial flows from international partners, and foreign capital has entered the financial and IT sectors. However, FDI is not directed toward the creation of technologically advanced or energy-intensive production and therefore does not generate a strong innovation effect.
2. Second, the number of innovative enterprises, as well as the share of innovative products in the total output of Ukrainian industrial enterprises, shows a general downward trend (Berdar et al., 2024, pp.30-31). High indicators of innovation-active enterprises during the war reflect the development of the IT sector, digitalization, and enterprises' adaptation through process innovations (online services, logistics, automation) rather than product innovations. An increase in the number of innovative products demonstrates structural renewal of the economy and growing technological flexibility of enterprises.
3. Third, R&D expenditures show an overall declining trend. Such expenditures typically decrease during crises (2014 and 2022). Unlike business innovation activity, the technological core remains chronically underfunded. This is primarily about financing the latest technologies, long-cycle defense and technological developments, and financing fundamental science in general.
4. Fourth, the war has negatively affected human capital, a key driver of innovation, due to a decline in living conditions in Ukraine, migration, and rising mortality.

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5. Fifth, the war has weakened the country's innovation potential, but Ukraine still maintains a certain position in global innovation chains, especially through the IT sector.

Thus, even during wartime, Ukraine demonstrates strong internal innovation potential; however, the investment model does not provide full technological development. Moreover, investment inflows are still directed mainly not toward innovation and advanced technologies, but toward the IT and financial sectors.

RESULTS

Econometric Modeling of the Impact of Innovation and Investment Development on Economic Growth, and Testing for Autocorrelation

Post-war recovery requires restoring and upgrading pre-war production levels and infrastructure based on energy-efficient and green technologies, which will require the effective use of direct investment. However, will direct investment in innovation contribute to building a competitive economy and economic growth in the post-war period? This issue can be addressed through an examination of the functional linkage between economic growth, measured by GDP, and key indicators of innovation and investment development.

To identify the relationship between economic growth and the selected innovation–investment variables, we apply a multiple regression method. The general form of the regression equation is:

$$GDP = C(1)*RDE + C(2)*Q + C(3)*K + C(4)*FDI + \varepsilon, \quad (3)$$

where C (1, 2 … n) – regression coefficients for the selected variables; ε – vector of random disturbances.

The correlation matrix constructed by the authors allows us to identify the relationships between the selected variables (Table 2):

Table 2. Correlation matrix of the selected variables. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

	GDP	RDE	Q	K	FDI
GDP	1	0.4228	0.2770	-0.2922	0.1238
RDE	0.4228	1	-0.3445	0.0968	-0.1328
Q	0.2770	-0.3445	1	0.0036	0.068
K	-0.2922	0.0968	0.0036	1	-0.1099
FDI	0.1238	-0.1328	0.068	-0.1099	1

The factors we studied, GDP and R&D, have a moderate and positive relationship, meaning that an increase in R&D expenditures contributes to GDP growth and is one of the key innovation-driven factors influencing the economy. The correlation matrix shows that the number of innovative enterprises and foreign investment in innovative sectors is very low in Ukraine's economy, and therefore does not serve as growth drivers. K (implemented innovative products) has a negative correlation with GDP, indicating low effectiveness of implementation or a delayed effect. Overall, there is no direct coherence among innovation indicators, demonstrating that the innovation system in Ukraine is fragmented. Thus, Ukraine's economic growth is most strongly linked to R&D expenditures.

The existence of causal links between the selected variables and economic growth (GDP) is assessed using the Granger causality test, which determines whether historical values of one variable contain predictive information about another. The results are evaluated on the basis of the F-statistic and the corresponding p-value (Prob). When the p-value falls below the conventional significance threshold of 0.05, the null hypothesis is rejected, providing evidence of a causal relationship. The analysis is conducted for lag lengths of 2, 3, and 4, with the outcomes reported in Table 3. The null hypothesis assumes the absence of causality between the variables.

Table 3. Pairwise Causality test on all the variables: Granger test, 2010-2024. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

N	Hypothesis: Null	Results	2 Lag			3 Lag		4 Lag	
			F-Stat.	p-value	Conclus.	F-Stat.	p-value	F-Stat.	p-value
1	RDE doesn`t Granger-cause GDP	RDE → GDP	4.51622	0.0487	reject	8.22502	0.0223	203.841	0.0049
	GDP doesn`t Granger-cause RDE		0.00735	0.9927	accept	0.42184	0.7457	0.54268	0.7291
2	Q doesn`t Granger-cause GDP	Q → GDP	12.6607	0.0033	reject	5.86518	0.0430	123.769	0.0080
	GDP doesn`t Granger-cause Q		0.27089	0.7694	accept	0.39185	0.7646	0.25907	0.8835
3	K doesn`t Granger-cause GDP	K → GDP	5.71242	0.0288	reject	3.51235	0.1049	3.57663	0.2303
	GDP doesn`t Granger-cause K		0.62871	0.5577	accept	1.26630	0.3803	0.69983	0.6598
4	FDI doesn`t Granger-cause GDP	FDI ↔ GDP	2.35014	0.1574	accept	1.31518	0.3671	2.67531	0.2901
	GDP doesn`t Granger-cause FDI		0.17566	0.8421	accept	0.18433	0.9027	0.61839	0.6943
5	Q doesn`t Granger-cause RDE	Q ↔ RDE	0.17011	0.8465	accept	0.10376	0.9543	2.51851	0.3039
	RDE does not Granger-cause Q		0.11246	0.8950	accept	0.85404	0.5216	0.28490	0.8682
6	K does not Granger-cause RDE	K ↔ RDE	0.15470	0.8592	accept	0.91220	0.4980	0.26795	0.8783
	RDE doesn`t Granger-cause K		0.35178	0.7138	accept	0.71096	0.5859	0.34867	0.8312
7	FDI doesn`t Granger-cause RDE	FDI ↔ RDE	1.63410	0.2541	accept	0.83788	0.5284	0.62480	0.6914
	RDE doesn`t Granger-cause FDI		0.18321	0.8360	accept	1.08133	0.4366	2.90350	0.2722
8	K doesn`t Granger-cause Q	K ↔ Q	3.61377	0.0762	accept	0.67195	0.6051	8.66563	0.1061
	Q doesn`t Granger-cause K		1.03930	0.3970	accept	1.37427	0.3518	2.49937	0.3056
9	FDI doesn`t Granger-cause Q	FDI ↔ Q	0.19579	0.8260	accept	0.09382	0.9602	0.55991	0.7209
	Q doesn`t Granger-cause FDI		1.06678	0.3884	accept	4.58416	0.0672	2.04926	0.3538
10	FDI doesn`t Granger-cause K	FDI ↔ K	0.28187	0.7616	accept	1.29723	0.3719	3.73455	0.2222
	K doesn`t Granger-cause FDI.		1.97268	0.2012	accept	1.39828	0.3459	0.86303	0.5991

The Granger test results (Table 3) confirm the presence of a one-way causal relationship between innovation indicators and Ukraine's economic growth for 2010-2024. The main findings are:

- First, R&D expenditures cause GDP growth at all lag levels (2, 3, and 4). No reverse effect was found between GDP and RDE. This means that increased R&D funding is a leading factor in economic growth, rather than a consequence of it.
- Second, the number of innovation-active enterprises (Q) also causes GDP growth at lags 2, 3, and 4. No reverse causality is observed. Thus, general innovation activity is an important driver of economic growth.
- Third, the number of implemented innovative products (K) affects GDP only at lag 2, but the effect disappears at higher lags. This indicates a short-term, limited causal effect of innovative products on economic growth.
- Fourth, in the context of innovation–investment development, FDI inflows into innovation in Ukraine are too small, meaning FDI does not cause GDP growth, nor does GDP attract additional FDI. Foreign direct investment does not act as a driver of economic development and does not respond to economic dynamics. This suggests that FDI is primarily directed into other sectors that generate economic growth (Tkalenko et al., 2021).
- Fifth, in all other cases, the test did not reveal causality between RDE, Q, K, and FDI in either direction. The elements of Ukraine's innovation system do not form a coherent, mutually reinforcing mechanism.

The Granger test results show that the two key factors driving Ukraine's economic growth are R&D expenditures (RDE) and the number of innovation-active enterprises (Q).

Regression analysis results presented in Table 4 make it possible to evaluate the impact of the selected variables on economic growth for the 15-year period (2010-2024).

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Table 4. Multi-factor regression: the results. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

Dependent Variable: GDP / Method: Least Squares				
Variable	**Coef.**	**Standard Error**	**t-Stat.**	**Prob.**
RDE	7760.665	2833.601	2.738800	0.0209
Q	163001.2	77294.65	2.108829	0.0612
K	-15596526	10074213	-1.548163	0.1526
FDI	0.311528	0.498701	0.624678	0.5462
C	113141.2	49387.45	2.290889	0.0449
R-squar.	0.524631	Mean dependent var		150895.3
Adj. R-squared	0.334483	S.D. dependent var		34202.26
S.E. of regression	27901.94	Akaike		23.57198
Sum squared resid	7.79E+09	Schwarz		23.80800
Log likelihood	-171.7899	Hannan-Quinn.		23.56947
F-statistic	2.759070	Durbin-Watson		1.243310
F-statistic (Prob.)	0.087951			

For the model, we use a significance threshold of 5-10% for evaluating factor quality. The results of the multiple regression model with GDP as the dependent variable indicate:

The R^2 value shows how much of GDP growth is associated with the selected variables. According to the regression results, 52.5% of GDP growth depends on the selected variables (correlation coefficient 0.5246), indicating a moderate relationship. The model explains approximately 33-52% of GDP variation (R^2 = 0.52, R_{adj} = 0.33). The likelihood of retaining the null hypothesis is negligible (F-statistic = 0.08), which provides support for the alternative hypothesis, indicating that the regression model is statistically significant overall at the 10% significance level. The constant is also statistically significant (below 5%), meaning that all indicators can be considered in the model. Without the influence of independent variables, GDP remains at a baseline level determined by factors not included in the model.

Only RDE (R&D expenditures) has a statistically significant effect. Its coefficient is significant at the 5% level (p = 0.0209). The positive sign indicates that increased R&D spending contributes to GDP growth, confirming the crucial role of innovation investment in economic development.

Innovation activity (Q) also has a positive effect and is significant at the 10% threshold (p = 0.0612). Thus, enterprise innovation activity may potentially contribute to GDP growth.

K (innovation implementation) has a negative but statistically insignificant coefficient, indicating the absence of a stable link between the number of innovative products and economic growth, likely due to low commercialization of innovations in Ukraine. FDI is also insignificant, confirming its limited role in innovation-driven economic growth during the study period.

Durbin–Watson = 1.24. Critical values: for n = 15, k = 4, α = 5% is 0,685 < DW < 1,977; for α = 1% is 0,488 < DW < 1,704. These values do not give a clear answer regarding the presence of positive autocorrelation of residuals. Therefore, we use an additional test. The presence of higher-order (second-order) autocorrelation is examined through the application of the Breusch–Godfrey test, with the results reported in Table 5. The results show Prob. F(2,7) = 90% and Prob. Chi-Square(2) = 82.6%, both well above the 5-10% significance threshold. Therefore, the null hypothesis is accepted, and the test confirms the absence of second-order autocorrelation.

The model's information criteria, namely the Akaike Information Criterion (AIC = 23.57) and the Schwarz Bayesian Criterion (BIC = 23.8), indicate an acceptable degree of model adequacy.

Regression analysis shows that Ukraine's economic growth during 2010–2024 depends primarily on internal funding of innovation.

Table 5. Correlation LM: test Breusch-Godfrey serial. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

F-stat.	0.104601	Prob. F(2,8)		0.9019
Obs*R-squared	0.382256	Prob. Chi-Square(2)		0.8260
Test Equation: Dependent Variable: RESID / Presample missing value lagged residuals set to zero.				
Variab.	Coef.	Standard Error	t-Stat.	Probably
RDE	14.71635	3141.656	0.004684	0.9964
Q	-18299.29	95481.10	-0.191653	0.8528
K	279682.3	11393708	0.024547	0.9810
FDI	0.042379	0.560254	0.075642	0.9416
C	-809.1220	54809.10	-0.014763	0.9886
RESID(-1)	0.226317	0.505156	0.448014	0.6660
RESID(-2)	0.122700	0.558958	0.219515	0.8317
R-squar.	0.025484	Mean dependent var		8.25E-12
Adj. R-squared	-0.705403	S.D. dependent var		23581.44
S.E. of regression	30795.27	Akaike		23.81283
Sum squared resid	7.59E+09	Schwarz		24.14326
Log likelihood	-171.5963	Hannan-Quinn		23.80931
F-stat.	0.034867	Durbin-Watson		1.429415
Prob(F-stat.)	0.999688			

Next, we perform a test for autocorrelation of the model's residuals (Table 6) to identify possible patterns or correlations among them. In the constructed model, all "prob" values exceed the significance level and remain around 90%. This indicates that the model can remain in its current form and does not require additional adjustments to account for auto-correlation in the residuals.

Table 6. Correlogram of residuals squared. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

	AC	PAC	Q-Statistic	Probably
1	0.008	0.008	0.0010	0.974
2	-0.107	-0.107	0.2273	0.893
3	0.041	0.043	0.2628	0.967
4	-0.014	-0.027	0.2673	0.992
5	-0.058	-0.049	0.3530	0.997
6	-0.096	-0.102	0.6144	0.996
7	0.055	0.048	0.7095	0.998
8	-0.113	-0.136	1.1750	0.997
9	0.041	0.065	1.2470	0.999
10	-0.111	-0.163	1.8765	0.997
11	-0.042	-0.019	1.9890	0.999
12	-0.201	-0.275	5.4335	0.942

Testing for Heteroscedasticity and Model Adequacy

The heteroscedasticity test is employed to assess whether the variance of the residuals is constant or varies in relation to changes in the independent variables. The outcomes of this diagnostic test are summarized in Table 7.

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Table 7. Heteroskedasticity test: the results. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

Test: Breusch-Pagan-Godfrey	**F-stat.**	**0.033369**	**Probably F(4,10)**	**0.9975**
	Obs*R-squared	0.197577	Probably Chi-Square(4)	0.9954
	Scal. explained SS	0.091272	Probably Chi-Square(4)	0.9990
Test: Glejser	F-stat.	0.101781	Probably F(4,10)	0.9793
	Obs*R-squared	0.586794	Probably Chi-Square(4)	0.9645
	Scal. explained SS	0.419756	Probably Chi-Square(4)	0.9808
Test: Harvey	F-stat.	0.864907	Probably F(4,10)	0.5173
	Obs*R-squared	3.855563	Probably Chi-Square(4)	0.4259
	Scal. explained SS	4.008548	Probably Chi-Square(4)	0.4049
Test: ARCH	F-stat.	0.005249	Probably F(1,12)	0.9434
	Obs*R-squared	0.006121	Probably Chi-Square(1)	0.9376

Analysis of Table 7 shows that all tests have high p-values, significantly exceeding the standard significance levels (0.01, 0.05, or 0.10), and approach 1. This means that the null hypothesis is not rejected. The variance of the residuals does not depend on the values of the independent variables, meaning that heteroscedasticity is not detected. The model exhibits no heteroscedasticity; the residuals have a stable, constant variance (homoscedasticity); the regression coefficient estimates are efficient and unbiased; and the OLS (ordinary least squares) method has been used correctly.

The next model verification is the test of residual normality, presented in Figure 1.

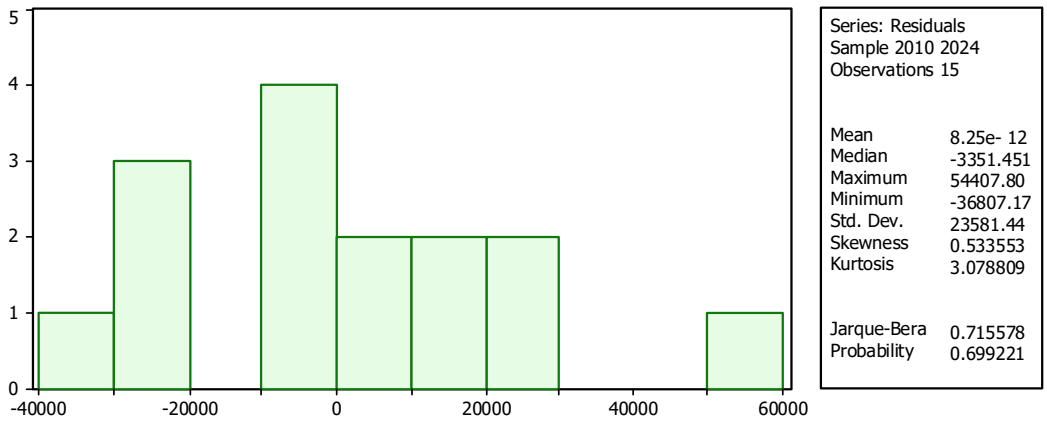

Figure 1. Normality test. *(Source: authors' development by the Multiple Regression procedure in EViews)*

An examination of Figure 1 indicates that the residuals follow an approximately normal distribution, as evidenced by the Jarque–Bera statistic of 0.71 and a p-value of 0.699, which exceeds the 5–10% significance threshold. The majority of observations are concentrated around zero, while the slight rightward shift is not considered substantial. Skewness is limited, and kurtosis remains close to its normal value, supporting the overall adequacy of the model. The residual distribution thus validates the application of the OLS method. A skewness coefficient of 0.533553 suggests a moderate positive (right) skewness, implying the presence of a limited number of extreme observations that slightly shift the mean to the right.

The model meets the key assumptions concerning normality, no bias, and the absence of systematic deviations. This means that the regression results are reliable and statistically valid. The test confirms that we accept the null hypothesis of normality of the residual distribution. Figure 1 shows a 69.9% probability of accepting H_0.

The fitted values of the model are presented in Figure 2.

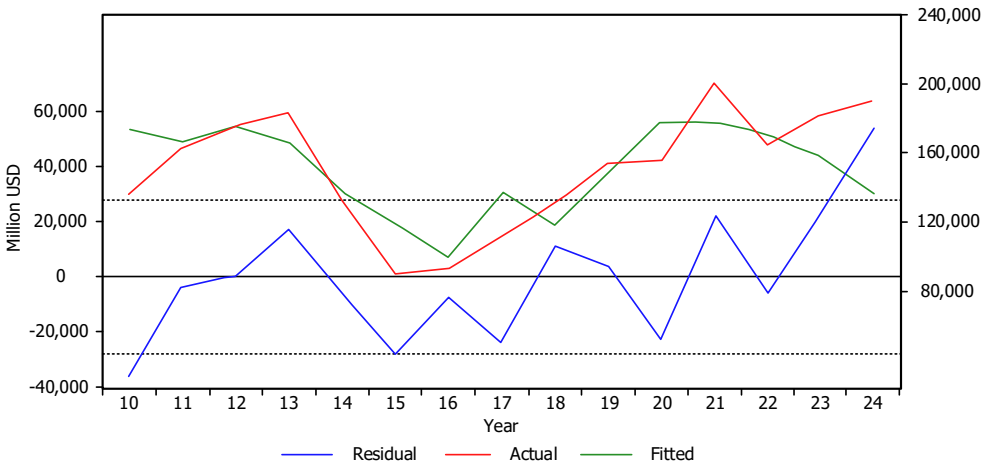

Figure 2. Explanatory ability of the model. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

The model (Fitted) reproduces the general trend of the actual data (Actual) fairly well, although it smooths over peaks (e.g., in 2013 and 2021) and troughs (e.g., in 2015-2017). This corresponds to the conclusion of moderate error, with a Variance Proportion of 16%. The residuals fluctuate around zero, confirming a Bias Proportion of 0%, although these fluctuations are significant in certain years (e.g., 2013 and 2021). Thus, the model contains errors, but they are unsystematic.

The forecasting results of the model GDP = f (RDE, Q, K, FDI) (Figure 3) show that MAPE = 12.3492, which is the mean absolute percentage error. The average forecast error is approximately 12.35%, which is a relatively high indicator, suggesting moderate model accuracy. At the same time, given the innovative-investment model under study (with limited influencing factors), an error margin of 10-15% can be considered acceptable, though not ideal.

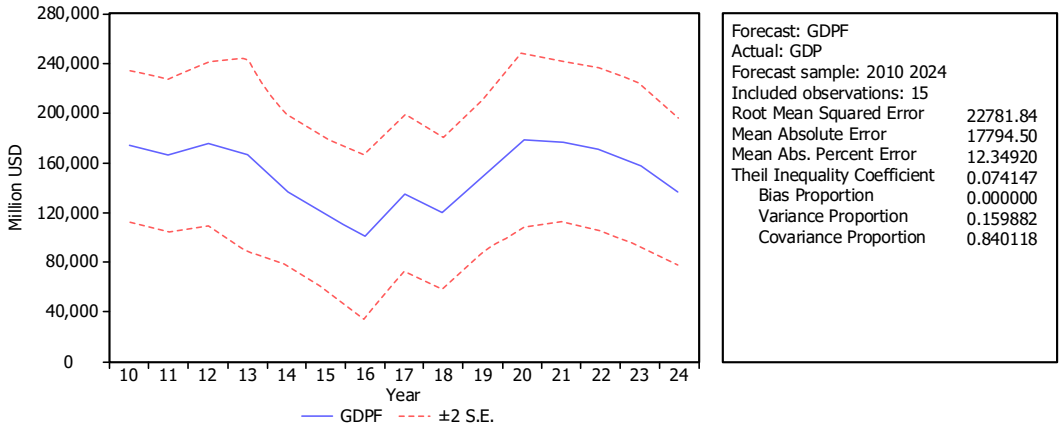

Figure 3. Forecast of GDP. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

Figure 3 demonstrates strong predictive power: the low Theil coefficient of 0.074 and the dominant Covariance Proportion of 84% indicate that the model significantly outperforms the naive forecast and successfully tracks the overall GDP dynamics. The graph visually confirms this and reproduces the overall pattern of actual dynamics relatively well, albeit smoothing its peaks.

Figure 3 shows a slow downward trend in GDP growth. According to our calculations, on average, in the next three years, under a realistic scenario, growth will be at the level of 3.4-3.1% (Table 8). At the same time, if we consider the most optimistic development scenario, which will provide for the end of the war in 2026, the use of various instruments to attract investments, control over their use, overcoming corruption, and effective state management, then these indicators may increase to 6-7% of GDP.

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Table 8. Forecast of GDP: the results to 2028. *(Source: authors' own calculations based on the multiple regression procedure implemented in eViews)*

Year	Forecast data (most realistic scenario), USD million	%
2025	194936.3	2.2
2026	201493.5	3.4
2027	208044.5	3.2
2028	214595.5	3.1

Thus, after all tests, we obtain the following statistically significant model with the substituted coefficients:

GDP = 7760.6654*RDE + 163001.1789*Q - 15596525.9776*K + 0.3115*FDI + 113141.1661 (4)

The authors constructed a multiple regression model that describes the dependence of gross domestic product (GDP) on four independent variables characterizing the innovation-investment development of the economy. The multivariate regression model has successfully passed all examinations; all tests confirm the validity of this model for Ukraine. This implies that:

- the estimated equation constitutes an economic–mathematical model of satisfactory quality;
- the equation is statistically significant and characterized by a moderate coefficient of determination;
- the model developed by the authors is adequate and can be reliably used for forecasting purposes, with an average deviation of approximately 12.35% from observed values.

DISCUSSION

Further discussion of this topic is relevant both for Ukraine and for other countries that may experience conflicts (wars), as well as for states seeking to modernize their economies in conditions of global competition. The world economy is evolving into an information-driven economy, where innovation, digitalization, investment, "green" technologies, renewable energy, high-tech production, and startups become the key drivers of economic growth. Attracting foreign investment in the context of an improved investment climate should be directed towards innovative technologies and the process of creating new products (Tkalenko et al., 2021, p.58). Countries that manage to attract investments into technologies more rapidly will gain competitiveness and promote economic growth.

During the war, Ukraine has developed innovations in the defense industry, facilitated digitalization, and expanded online technologies (particularly in education). In the post-war period, waves of investment inflows are expected; Ukraine will gain access to new investment markets, contributing to the modernization of infrastructure and production chains and integration into high-tech projects.

Our article examines the formation of an innovation-investment model of development at the macroeconomic level, while in the article, Audretsch D. et al. reveal the role of an innovation-investment strategy through industry cooperation and knowledge dissemination in the industry for innovations at the micro level, through enterprises (Audretsch et al., 2024). The common approach is to attract national investments, invest in national innovations, disseminate knowledge for the implementation of innovations, and cooperate with other entities.

Our research is focused on building a new model of economic development of the country, using the advantages in post-war recovery – assistance from partner countries, namely, the EU, Canada, the USA, Japan, and others. This article differs, for example, from the article by Malynovska Y. et al., which reveals the innovation and investment priorities of sustainable recovery at the micro level of Ukrainian enterprises, mainly in the L'viv region (Malynovska et al., 2025). Our research analyzed the indicators of all regions of Ukraine, as well as the global rankings of Ukraine. The common thing in the research is that we analyzed the current state of innovation activity and investment dynamics in Ukraine, but for different interval periods. The novelty of our research is the possibility of presenting the design of a model of innovation and investment development of the country in post-war recovery, while considering certain limitations.

This study is presented at a macro level, which distinguishes it from most other publications, both foreign and domestic, and has several limitations. The first limitation is that four independent variables were investigated that characterize the innovative and investment development of the economy in the conditions of an ongoing war and daily increasing losses;

in a year, the research design will have a different look. The second limitation is that the selection of control variables does not take into account qualitative factors that require additional research. Future researchers can expand the analysis with components that will allow for a more complete view of the design of the innovative and investment model, taking into account endogenous and exogenous influences.

Our focus was on quantitative indicators of innovation-investment development, but the impact of qualitative factors should also be explored in the future, as they may change the paradigm of innovation-investment development. Moreover, for post-war reconstruction, priority areas must be identified, which is also a subject of discussion. It is expected that FDI will be directed toward high-tech sectors, R&D funding will increase, strategies for restoring human capital will be developed, and innovation-investment clusters will be created.

The situation in Ukraine regarding economic growth, investment, and innovation in 2026 is contradictory, yet not hopeless. Economic growth continues, albeit at a slow pace (forecasts by international organizations and the National Bank of Ukraine are revised annually). At present, investment inflows remain limited, and a significant share of financing is provided by international assistance rather than private capital. Innovation activity retains its potential; however, its development is constrained by high risks and persistent instability. At the same time, Ukraine demonstrates macroeconomic resilience even amid a prolonged war. Nevertheless, in order to accelerate growth, enhance investment attractiveness, and stimulate innovation activity, further reforms, economic diversification, and a peaceful settlement of the conflict are required as key factors for improving long-term prospects. These aspects may be debated and broaden the scope of the research.

CONCLUSIONS

As a result of the conducted research, when assessing the current state of Ukraine's innovation and investment development, particular attention should be paid to certain features of the adaptive model of functioning of the national economy under wartime conditions. The analysis of key quantitative indicators – FDI inflows, the number of innovation-active enterprises, the number of introduced types of innovative products, R&D expenditures, the Human Development Index, and the Global Innovation Index ranking – makes it possible to highlight the following generalizations:

1. First, after a deep economic decline in the first year of the full-scale war, there has been a gradual recovery of business activity and stabilization of macroeconomic indicators. Real GDP shows slight growth, indicating the presence of the economy's adaptive potential. At the same time, investment activity is characterized by a high dependence on international financial support.
2. Second, FDI inflows have significantly decreased compared to the pre-war period, due to increased security risks, legal uncertainty, and limited long-term predictability. However, there has been a gradual recovery of investment flows into strategically important sectors – IT, energy, agro-processing, and the defense technology sphere – indicating the emergence of new points of economic resilience.
3. Third, the innovation component of development retains its potential; however, its quantitative parameters remain structurally constrained. The share of expenditures on research and development in GDP is low, indicating underfunding of the basic infrastructure of knowledge and technology. The number of innovation-active enterprises and the volume of implemented innovative products demonstrate uneven dynamics, reflecting the predominantly adaptive nature of innovation, namely, a focus on short-term technological solutions and process digitalization rather than the creation of breakthrough full-cycle technologies.

As a result of the regression analysis of the impact of innovation-investment development factors in Ukraine on GDP during the study period, modeling and forecasting were carried out, leading the authors to identify:

- a positive impact of R&D expenditures: an increase in R&D spending by USD 1 million leads to an increase in GDP by USD 7,760.67 million, which is an extremely high multiplier, likely due to correlations among variables and model specifics. We believe that an increase in R&D expenditures in Ukraine may have a systemic and long-term positive effect, manifested not only in GDP growth but also in the formation of an innovation-oriented economy and an increase in the share of value added in production (which is particularly relevant for the agricultural sector, which accounted for 59% of total exports in 2024 (NISS, 2024). To enhance the effectiveness of the state's innovation and investment development model, it is necessary to introduce new technologies in industry, energy, agriculture, and IT, modernize production capacities, promote the reduction of energy intensity and resource consumption, and foster the development of green and digital technologies that comply with EU standards, which will lead to economic growth and accelerate the path toward EU integration. It should be noted that increasing R&D expenditures yields the maximum effect only under conditions of transparent and efficient use of funds, strong links between science, business,

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and production, and the availability of institutional support (protection of intellectual property rights, anti-corruption measures and mechanisms, and a stable economic policy);

- a positive impact of innovation-active companies—an increase of 1,000 such enterprises results in GDP growth of USD 163.0 million. This shows that enterprise innovation activity is a powerful driver of GDP. Under such conditions, exports of high-tech products and services will increase, and domestic enterprises will become more competitive in global markets;
- an increase in FDI by USD 1 million leads to an increase in GDP of only USD 0.3115 million. The coefficient is below one, which may indicate that FDI in Ukraine has a relatively low direct multiplier effect on GDP, or that a large share of investment goes into sectors with quick returns. Statistical analysis has shown that, to date, limited investment has been directed toward R&D; however, in the authors' view, investments in R&D make a country more attractive for high-quality, technology-oriented foreign direct investment rather than investments focused solely on financial operations, thereby strengthening the investment multiplier effect. Also, attracting FDI in innovation will have a greater return in the long term, leading to economic growth;
- the indicator of introduced types of innovative products does not correlate with GDP. According to the authors, this result may stem from the low efficiency of implemented innovations or the fact that innovation implementation requires high short-term costs and has not yet generated returns (time-lag effect).

Other innovation-investment factors analyzed demonstrate weak relationships, indicating an inefficient innovation system, low impact of innovative products, and a limited role of FDI in innovation-driven development. Stable causal links between individual elements of the innovation system (RDE, Q, K, FDI) are absent, indicating fragmentation and low synchronization of the innovation environment.

The practical significance of the research on the role of innovation- and investment-driven development as a factor of economic growth for Ukraine's post-war economy is high, defined by the unique opportunities opening up for the country as well as the urgent need for qualitative modernization of various infrastructure facilities and enterprises, many of which have been destroyed. At the same time, it should be emphasized that economic growth in Ukraine depends more on internal innovation factors than on external investment. In addition, the effect of implementing the innovation and investment model is definitely long-term. The formation of an innovation and investment development model will contribute to making the domestic economy more flexible and resilient to external shocks. Post-war recovery should transition toward qualitative modernization based on new technologies, which will form the foundation for long-term sustainable development.

Future research in the model of innovation and investment development of the state in the post-war period may also include qualitative variables, which will allow for a more complete design of the model. The difficulty of introducing qualitative variables lies in the fact that the war in Ukraine continues, and these indicators change daily. It is difficult today to analyze the losses incurred by enterprises that require even greater renewal of the material and technical base and implementation of innovative technologies. It is also worth exploring other quantitative indicators in the future, which depend on the subjective position of donor countries.

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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Ткаленко С., Дерій Ж., Корявець М., Полянський М., Данилевський Р., Децюк П.

ІННОВАЦІЙНО-ІНВЕСТИЦІЙНА МОДЕЛЬ РОЗВИТКУ ДЕРЖАВИ ЯК ЧИННИК ЕКОНОМІЧНОГО ЗРОСТАННЯ В ПОВОЄННИЙ ПЕРІОД УКРАЇНИ

У статті розглянуті актуальні проблеми інноваційно-інвестиційного розвитку держави на прикладі України в повоєнний період. Увага авторів зосереджена на тому, що інноваційно-інвестиційний розвиток є ключовою рушійною силою для повоєнної відбудови й необхідною передумовою економічного зростання. Стратегія повоєнної відбудови надає можливість для стрибка в якісно нову модель розвитку, для якої необхідні прямі інвестиції та новітні технології. У досліджені автори акцентують увагу на кількісних інноваційно-інвестиційних індикаторах, таких як витрати на НДР, кількість інноваційно активних компаній, прямі іноземні інвестиції. Розглядають гіпотезу, що інноваційно-інвестиційний розвиток України позитивно впливає на економічне зростання (збільшення ВВП) країни. Проаналізовані основні індикатори інноваційно-інвестиційного розвитку України і визначено, що Україна навіть у стані війни демонструє потужний внутрішній інноваційний потенціал, але інвестиційна модель не забезпечує повноцінного технологічного розвитку. На основі аналізу функціональної залежності між економічним зростанням (через ВВП) та індикаторами інноваційно-інвестиційного розвитку автори розробили модель і здійснили прогнозування. Автори дійшли висновку: збільшення витрат на НДР матиме системний і тривалий позитивний ефект, який проявляється не лише в зростанні ВВП, а й у формуванні інноваційно орієнтованої економіки та підвищенні частки доданої вартості у виробництві; зростатиме експорт високотехнологічної продукції та послуг, а вітчизняні підприємства стануть більш конкурентними на світових ринках. Інноваційно-інвестиційна модель розвитку економіки України має прояв через тривалі ефекти. Зростання витрат на НДР може стати одним із найпотужніших драйверів економічного зростання України, технологічного прориву та успішної євроінтеграції, особливо в повоєнний період.

Об’єктом дослідження є процеси економічного зростання та розвитку національної економіки України в повоєнний період, що формуються під впливом інноваційно-інвестиційної моделі розвитку. Предметом дослідження є механізми формування, особливості реалізації інноваційно-інвестиційної моделі розвитку держави та її вплив на економічне зростання України в повоєнний період.

У досліджені використано принципи системного підходу при розкритті індикаторів інноваційно-інвестиційного розвитку на економічне зростання в повоєнний період, принцип вірогідності, який відображає сучасний стан національного економічного розвитку, і принцип інформаційної доступності та репрезентативності для можливості обґрунтування результатів дослідження.

Ключові слова: інноваційно-інвестиційний розвиток, повоєнна відбудова, економічне зростання, інноваційні технології, прямі інвестиції, євроінтеграція, цифровізація, «зелені» технології, модернізація

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