https://doi.org/10.15407/scine20.06.048
SKRYPNYCHENKO, M. I. (https://orcid.org/0000-0003-3804-9857),
NYKYFORUK, O. I. (https://orcid.org/0000-0001-7376-3373),
BILOUSOVA, O. S. (https://orcid.org/0000-0001-7434-3469),
STASIUK, O. M. (https://orcid.org/0000-0002-4701-5598),
FEDIAI, N. O. (https://orcid.org/0000-0002-6529-1078),
BILOTSERKIVETS', O. H. (https://orcid.org/0000-0003-0051-2877),
and KUZNETSOVA, L. I. (https://orcid.org/0000-0001-8711-7487)
Institute for Economics and Forecasting of the National Academy of Science of Ukraine,
26, Panasa Myrnoho St., Kyiv, 01011, Ukraine,
+380 44 280 1234, gvm@ief.org.ua

INVESTMENT ATTRACTIVENESS AND MULTIPLIER EFFECTS FOR THE NATIONAL ECONOMY FROM THE DEVELOPMENT OF THE TITANIUM INDUSTRY

Introduction. *The development of titanium production in Ukraine through the creation of a full cycle of production should become a priority in the policy of development of strategic types of activities and correspond to national interests in the country's economy.*

Problem Statement. *Ensuring domestic needs for metallic titanium and increasing its export in the future requires the development of high-tech industry, in particular, the production of finished products of metallic titanium. It is important to calculate the macroeconomic effects of the development of titanium production.*

Purpose. *To justify the attractiveness of projects for investors and to evaluate the macroeconomic multiplier effects of the development of titanium production in Ukraine in the direction of in-depth processing of raw materials and the manufacture of finished products.*

Materials and Methods. *The basis of the study is the construction of a system of balanced indicators for assessing the attractiveness of the investment project for the state, domestic and foreign investors. Calculations of multiplier effects for the economy were made on the basis of the input-output datasheets in basic prices due to increases in gross output and gross added value for the type of economic activity.*

Results. *A multi-stage study of the investment project of the construction of a new titanium plant and the impact of the development of the titanium industry on the economy of Ukraine was carried out based on the calculations of the multiplier effects of national significance. Methodological approaches are shown, which are also appropriate for other strategically important promising types of industry in the post-war period.*

Conclusions. *The development of a complete closed cycle for the production of metallic titanium and products from it requires the formation of a state policy to stimulate investors in terms of the formation of favorable conditions for their activity. This is indicated by the obtained evaluations of the attractiveness of the titanium investment project, the results of the multiplier effects of the increase in gross output and the expected growth in gross added value, in particular, when transitioning from the production of titanium sponge to the production of finished titanium products.*

Keywords: titanium industry, investments, full-cycle production, investment project, multiplier effects, gross output growth, gross added value, input-output datasheet, scenario calculations.

Citation: Skrypnychenko, M. I., Nykyforuk, O. I., Bilousova, O. S., Stasiuk, O. M., Fediai, N. O., Bilotserkivets', O. H., and Kuznetsova, L. I. (2024). Investment Attractiveness and Multiplier Effects for the National Economy from the Development of the Titanium Industry. *Sci. innov.*, 20(6), 48—66. https://doi.org/10.15407/scine20.06.048

The development of titanium production in Ukraine, through the establishment of a full production cycle, is a national priority and aligns with the country's economic interests. This is reflected both in pre-war documents, such as the National Security and Defense Council (NSDC) decision dated July 16, 2021, on Stimulating the Search, Extraction, and Beneficiation of Minerals of Strategic Importance for the Sustainable Development of the Economy and Defense Capability of the State, as enacted by Presidential Decree No. 306/2021 on July 23, 2021, and in more recent wartime policies. For instance, Resolution No. 132 of the Cabinet of Ministers of Ukraine, dated February 14, 2023, includes titanium deposits in the list of strategic resources critical for the sustainable development of the country's economy and defense capability.

Establishing a full titanium production cycle in Ukraine will facilitate the accelerated growth of medium and high-tech sectors in the processing industry, particularly those with high value-added potential, such as the defense-industrial complex, aviation, energy, metalworking, mechanical engineering, the chemical industry, and the medical sector (for the manufacture of tools, implants, and prosthetics). Titanium is especially crucial for Ukraine's defense industry, including the rocket and space sector, aviation, shipbuilding, and tank manufacturing, as well as for producing consumer goods. The use of titanium and its alloys is also expanding in chemical, energy, heavy transport engineering, and industries like food processing, light manufacturing, and precision instrumentation (equipment, pipelines, containers for aggressive environments, heat exchange equipment, filters, pumps, and more).

As shown below, the production of end-use products from metallic titanium and its alloys can be technologically realized in Ukraine, leveraging the latest domestic R&D advancements — primarily from the National Academy of Sciences of Ukraine — and the country's well-developed mining and processing industries. Ukraine has a substantial mineral raw material base for titanium, accounting for 1.12% of the world's titanium ore reserves.

Experts have noted that even before the war, Ukraine was developing only about 10% of its explored titanium reserves. Despite this, the country accounted for 5.11% of the world's ilmenite concentrate production and 15.1% of the world's rutile concentrate production. Additionally, Ukraine produced up to 5% of the global supply of titanium sponge, with two-thirds of this production being exported. Given the strong external demand for titanium and its derivatives, along with the potential for developing a domestic market for titanium products for both industrial and consumer use, establishing a full-cycle titanium production industry should be a national priority in the strategic development agenda.

Before the full-scale invasion by the Russian Federation, each stage of metallic titanium production in Ukraine was marked by interstate specialization. After titanium ore was extracted in Ukraine, it was processed into titanium concentrate, with about two-thirds of this concentrate being exported, while the remaining one-third was used domestically to produce titanium sponge. The titanium sponge produced in Ukraine was largely exported to Russia, where it was further processed into ingots. These ingots were then sent to the United States, where they were transformed into rolled products, which were subsequently distributed worldwide for the production of a broad range of items at numerous facilities.

Before the full-scale war, between 70% and 85% of Ukraine's titanium ores and concentrates were exported, with domestic consumption accounting for just 15% to 30%. The situation was even more skewed for titanium sponge, where exports comprised almost 80% to 90% of total production. Over the period from 2019 to 2021, Ukraine earned USD 570 million from the export of titanium ore, concentrates, and sponge, with 78% of these revenues coming from the export of ores and concentrates.

However, Ukraine's pre-war focus on extracting and exporting raw materials and low-tech products from titanium ore does not align with the needs of a post-war economy. Such a speciali-

zation cannot support the conditions necessary for sustainable development or ensure the defense capability of the country. Moving forward, the development of a full-cycle titanium production industry is essential for Ukraine's economic resilience and national security.

The war has significantly disrupted Ukraine's specialization in titanium production. Given the urgent need to meet domestic demands for metallic titanium and the potential for expanding titanium production for international markets, Ukraine must overcome the fragmentation of its production processes and better integrate into global value chains. According to research by R. Rowe and his colleagues, these global chains are expected to expand further. Therefore, it is imperative for Ukraine to focus on developing high-tech industries, including the production of finished titanium products.

To explore the potential for expanding titanium production across its entire development cycle, several key factors must be considered. First, it is crucial to assess the investment attractiveness of titanium-related projects for both foreign and domestic investors. This assessment should highlight the achievements of Ukrainian science and innovation. Second, an evaluation of the multiplier effects on the national economy resulting from the development of titanium production, particularly in the areas of raw material processing and finished product manufacturing, is essential.

Conducting these assessments and recognizing the strategic importance of developing a high-tech titanium industry will elevate Ukrainian industry to a new, mature level, thereby enhancing the economy's competitiveness in the global market. Since the development of titanium production in Ukraine involves not only the production of metallic titanium but also the manufacture of a wide range of products for various economic sectors, launching such a large-scale project will have a substantial impact on Ukraine's economy through significant multiplier effects.

Addressing the challenges related to the development of titanium production in Ukraine can benefit from the theoretical frameworks established by economists like R.F. Kahn, J.M. Keynes, and P. Samuelson, among others. Their research on the theory of the multiplier and its effects has been widely utilized to assess the dynamic impacts of economic changes. Practical applications of these theories, particularly in evaluating the consequences of investment projects and their effectiveness, are documented in various studies.

The successful development of the titanium industry, particularly from the perspective of the multiplier effect, requires a detailed understanding of how it influences related economic activities. This involves illustrating the effectiveness of the multiplier process and examining existing models for calculating the investment multiplier, specifically the Keynesian model and the input-output model. A systematic analysis of these models, including their applicability to the Ukrainian context, is essential for informed decision-making.

Scenario-based studies have also been conducted to explore the macroeconomic effects of attracting investments, achieving high rates of fixed capital accumulation, and maintaining moderate inflation. These studies aim to identify key driver industries that could expedite the post-war recovery of Ukraine's economy.

Furthermore, sector-specific models of multiplier effects have been developed, which assess the impact of investment infusions on various business sectors, such as commercial real estate. For instance, the assessment of multiplier effects for the national economy from the construction of the first stage of the Dniester HPP between 2010 and 2019 provides valuable insights into the socio-economic significance of such projects.

By leveraging these theoretical and practical frameworks, Ukraine can better navigate the complexities of expanding its titanium production capabilities, ensuring that the benefits extend across multiple sectors of the economy.

Bida M. [17] explores the relationship between economic growth and foreign trade, specifically analyzing the concept of the foreign trade multiplier. It includes calculations of the multiplier for

Central and Eastern European countries, offering insights into potential economic growth rates for the region based on export growth and capital investments. This analysis is particularly relevant for our research, as it can inform calculations of the multiplier effects associated with the export of titanium products.

The issue of assessing multipliers and their effects extends beyond just industrial investments, as seen in other areas of economic activity. For instance, study [15] emphasizes the importance of identifying priority areas for the development of the agrarian economy, particularly under transformational conditions, by studying the challenges of evaluating multiplier effects.

In the context of infrastructure, the experience of assessing multiplier effects in railway transport activities, especially regarding large-scale investment projects, offers valuable lessons. The outcomes of these multiplier calculations are detailed in [16], which highlights the broader impact of such projects on the national economy.

Moreover, research [14] provides an analysis of the multiplier effects of investments in residential construction, demonstrating that investments in this sector generate greater multiplier effects compared to other industries. The study also discusses the key instruments of state regulation in the real estate market that can enhance these effects, offering practical insights into how targeted investments in construction can drive broader economic benefits.

Drawing on these diverse studies, it becomes clear that evaluating multiplier effects is crucial across various sectors, from residential construction to agrarian development and infrastructure projects. By applying these principles to the titanium industry in Ukraine, it is possible to better understand and maximize the economic impact of investments in this strategically important sector.

In [18], Prokopov O.A. has studied the manifestation of the multiplier effect on the competitiveness of the national economy in the international market for information services. This aspect is critical for understanding the broader implications of economic competitiveness on a global scale. Given that the development of titanium production in Ukraine is expected to significantly boost exports in the future, this experience provides valuable insights for our research.

Shadura-Nykyporets N.T. and Minenko, O.V. [19] delves into similar themes, though the focus is somewhat more regional. Meanwhile, Doroshkevych D.V. [20] examines the theoretical aspects of investment processes within regional systems, analyzing various multiplier theories and defining a regional investment expansion coefficient. This coefficient helps identify which types of investments yield the most substantial expansion effects on the regional economy. The territorial expansion of titanium ore reserves and the development of related industries will likely have a significant effect on the regions where these activities are concentrated.

Given the interdisciplinary nature of titanium production development, the analytical report on the influence of the nuclear energy complex on Ukraine's development [21] is of particular scientific interest. This report provides a comprehensive assessment of the nuclear energy sector's impact on Ukraine's economic development, including a partial evaluation of the closed-loop development of titanium production in the country.

Furthermore, the influence of changes in final product usage on the output of various Ukrainian economic sectors, alongside an integral indicator that considers output multipliers, wages, and the stability of these values over time, has been studied by Chepeliev M.H. [22]. Research of Horobinska I.V. [23] is also relevant, as she has assessed the effects of the multiplication mechanism in adjacent sectors of the economy, particularly within the transport sector, through the lens of intersectoral balance.

These studies collectively offer a robust foundation for understanding the potential multiplier effects of expanding titanium production in Ukraine. By leveraging these insights, it is possible to gauge the broader economic impacts and identify

strategic opportunities for enhancing the country's industrial capabilities and economic resilience.

The presented review of scholarly research publications on the assessment of multiplier effects from investment activities, particularly in relation to economic development dynamics at both macroeconomic and sectoral levels, demonstrates that a solid theoretical and methodological foundation for studying these effects has been established. This foundation is evident not only at the macroeconomic and regional levels but also in specific sectors of the economy.

Despite substantial theoretical advancements in understanding the formation of multiplier effects in the economy, including contributions from the authors of this study, much of the existing research has focused on calculating Keynesian-type multipliers (investment multipliers), particularly in sectoral and regional analyses. However, more complex and practical calculations, such as those based on the input-output datasheets, which offer insights into specific types of activities available in aggregated inter-industry balances, have not yet gained widespread application.

In the initial phase of this study, the systematization of R&D related to titanium production technologies and their derivative products was conducted, drawing on the advancements of academic science. The subsequent phase involved the technical and economic justification of an investment project for the construction of a modern factory equipped for the full-cycle production of titanium products. This justification was grounded in the implementation of certified technologies and equipment, such as electron-beam melting, vacuum-arc remelting, and rolling, as well as domestic innovations in producing new titanium alloys with enhanced operational characteristics and novel methods of manufacturing titanium products.

The evaluation of this investment project, which encompasses the creation of production facilities, an innovation and R&D center (including a research and development base to facilitate the development, testing, and implementation of breakthrough technologies and the discovery of new properties of titanium to meet consumer demands), and an educational center for labor force training and skill enhancement, required the formation of a comprehensive system of indicators. These indicators include established metrics for assessing project cash flows, financial returns on investment costs, capital returns, financial stability, and other financial and economic analyses. Additionally, the evaluation involved market, institutional, and budgetary analyses, project risk assessments, and indicators of the benefits derived from integrating innovations into production, all aimed at ensuring medium- and long-term profitability for investors.

Given that the implementation of large-scale investment projects requires substantial financial support, typically involving co-financing from the state, domestic, and foreign investors — each with different priorities and requirements for evaluation methodologies — this study has summarized various approaches to evaluation. These include those defined by Ukrainian regulatory acts concerning the evaluation of investment projects with significant investments, European Commission regulations on assessing large investment projects (specifically regulations No. 1303/2013, No. 207/2015, and No. 1060/2021), the European Commission's guidelines for cost-benefit analysis of investment projects, methodological recommendations from the European Investment Bank, and methods employed by international investment groups and auditing and consulting firms that conduct professional evaluations for private investors.

By building a system of balanced assessment indicators, this study was able to evaluate the investment attractiveness of the project for the state, as well as domestic and foreign investors.

At the third stage, to comprehensively assess the potential impact on the national economy of developments in the titanium industry in Ukraine, this study presents two methodological approaches for calculating multiplier effects. Both approaches are based on the use of the input-output datasheet (IOD) but differ slightly in their

calculations due to the limited availability of verified statistical data. The use of these two complementary approaches enhances the reliability of the results, which is particularly important when making scenario-based assumptions regarding the gross value added and gross output over the long term (up to 10 years).

The calculations of multiplier effects on the economy are derived from increases in gross output and gross added value for a specific type of economic activity. These calculations are based on the IOD at basic prices for the corresponding foreign exchange and assume full provision of production with the necessary resources (including previously accumulated reserves formed within related economic activities) and labor force.

To accurately assess the impact of the development of a specific economic activity (EA) on economic dynamics in Ukraine, it is most effective to use the input-output datasheet, also known as the Leontief model [24]. This model is based on the concept of interrelationships between different economic activities, where each industry consumes goods and services produced by other industries. The input-output table allows for the analysis of the economic system's sensitivity to changes in various components, particularly changes in production dynamics across specific sectors. This approach ensures comparability and balance between the indicators used.

According to the first approach, the input-output datasheet shall be modified by separating a distinct "item" or "row and column" to isolate and clarify the effect of metallic titanium production (EA 25 *Production of Titanium and Titanium Products*) on Ukraine's economy. This requires adjusting the data associated with EA 24 (*Metallurgical Production*). This modification was implemented during the research to conduct practical calculations for assessing direct, indirect, and induced contributions (the results of which are presented below). In this context, the term "multipliers" refers to the coefficients that illustrate the relationship between the magnitude of the effect (e.g., increase in output, gross value added in the overall economy) and the initial increase in the production of metallic titanium and its products, which triggers this effect.

$$M_{out} = \Delta X / \Delta X_{25}, \quad (1)$$

where M_{out} is the multiplier of the increase in the production of titanium and its products in accordance with the increase in the total production of goods and services in Ukraine; ΔX is the increase in the total output of products and services at basic prices in Ukraine; ΔX_{25} is the increase in the production of titanium and its products in basic prices.

$$M_{va} = \Delta VA / \Delta X_{25}, \quad (2)$$

where M_{va} is the multiplier of the increase in the production of titanium and its products in accordance with the increase in the total GVA in Ukraine; ΔVA is the increase in the total VAT in Ukraine; ΔX_{25} is the increase in the production of titanium and its products in basic prices.

Multiplicative effects refer to the changes in macroeconomic indicators, such as gross output and gross value added (GVA), resulting from growth in a specific sector, such as EA 25 (*Production of Titanium and Titanium Products*).

In general, these effects can be categorized into three types:

1. Direct Effect: This effect arises from an increase in production output within the titanium industry. It includes:

- An increase in output.
- A rise in the added value created within the sector.
- Higher wages for employees directly engaged in the titanium industry.

2. Effect Without Considering Added Value Growth: This effect results from the increase in intermediate consumption of goods and services within the sector. The multiplier for this effect shows how much gross output — and consequently, added value — increase due to a rise in production output in the titanium industry, excluding the effect of wage growth. Essentially, it reflects the expansion of production costs without accounting for the added value generated across the economy.

3. Indirect Effect: This effect is related to the increase in added value generated from higher consumer spending. It occurs when employees' wages rise due to increased production, leading to higher household consumption. The key objective is to assess how increased household spending, fueled by higher wages, boosts final demand for domestic products and services.

By evaluating these effects, we can understand the broader economic impact of expanding production in the titanium sector and its influence on various economic indicators.

The effect of increasing wage payments to employees, which constitutes one of the components of added value, arises from the formation of additional income for the population. This income is generated by the growth in output within Ukraine's economy and leads to increased household consumption — one of the elements of final demand. This, in turn, promotes further production expansion and amplifies the multiplier effect.

Key Assumptions in the Calculations are as follows:

- **Constancy of Direct Costs:** The technical coefficients, representing direct costs, are assumed to remain unchanged. The initial output increase is attributed to a rise in exports.
- **Stable Structural Parameters:** Structural parameters such as the final demand composition and the import intensity of cost elements and final demand remain constant.
- **Capacity Utilization:** Additional demand for domestic goods, resulting from the multiplier effect, can be met by utilizing existing production capacities.
- **Zero Increase in Commodity Stocks:** The increase in commodity stocks within the economy is assumed to be zero.
- **Income Elasticity:** Demand elasticity concerning income is assumed to be one.

The second approach involves calculating multiplier effects based on output growth and GVA growth, using the *Metallurgical Production* FDI matrix. This approach does not detail the analysis as the first approach does. The multiplier effects from output increases occur under the condition that production is fully supplied with necessary resources, including previously accumulated reserves and labor force.

To determine these multiplier effects, coefficients of direct and total costs are calculated with the use of data from the IOD at basic prices. This process involves constructing auxiliary matrices:

- **Matrix of Direct Costs:** Shows direct costs associated with production.
- **Single Matrix:** Provides a simplified view of cost relationships.
- **Matrix of Total Costs:** Reflects the total costs including direct and indirect costs.

The sum of the coefficients in the total costs matrix for a given column indicates how much gross output for all examined economic activities increases when the output of the final product in this economic activity increases by one unit.

The Input-Output Datasheet that is submitted annually by the State Statistical Service of Ukraine, includes import values and can be used to estimate multiplier effects. However, imports can inflate the magnitude of these effects. This issue can be mitigated either by excluding imports from the calculations or by applying a matrix that focuses exclusively on the use of domestically produced goods, as was done in this study.

The production multiplier for a specific Economic Activity (EA) indicates the growth in output resulting from an increase in production within that EA, without considering the effect of added value growth. This multiplier is calculated by established methodologies, such as those detailed in [30—34]. The resulting output multiplier for the corresponding EA allows us to estimate the multiplier effect on Ukraine's economy from increasing output within that specific EA for a given year.

Multiplier effects are also calculated by considering increases in the components of Gross Value Added (GVA) within the relevant EAs, including wages, taxes, and profits. The determination of multiplier effects on the economy due to wage increases, as a component of GVA in the relevant EAs, involves "locking" the increase in the

GVA component — specifically, wages — to the corresponding increase in household final consumption expenditures [35, 36].

The calculation process begins by determining the increase in wages and the elasticity coefficient between wages in the relevant EA and household final consumption expenditures. The multiplier effect resulting from wage growth, or the increase in household consumption expenditures on domestic products, is calculated according to the approach detailed in [37, 38].

The implementation of investment projects for the development of titanium production at advanced technological stages requires a shift in emphasis within this study, moving from the analysis of ore extraction, concentrate production, and titanium sponge manufacturing to the development of titanium product manufacturing. This includes products such as rods, bars, wire, pipes, titanium ingots produced via electron-beam melting and vacuum arc remelting, rolled products, and titanium items manufactured by 3D printing technology (e.g., turbines, engines, parts, and components). Titanium products are crucial for supporting the defense industry, as well as the aircraft, automobile, and shipbuilding industries, and various other engineering sectors, including the medical and chemical industries.

These types of production are the most profitable. For example, calculations show that the export value ratio of 1 ton of titanium sponge compared to the average export value of ores and concentrates is more than 27 times higher, and for titanium products, it is over 92 times higher, as shown in Table 1 (column 4). The data indicate that the effectiveness of export deliveries for certain types of products (titanium sponge, titanium products) is 6.4 times higher for sponges and 14 times higher for titanium products (such as profiles, wire, etc.) (column 5). This is a natural outcome, as the proportion of added value increases with each technological advancement.

There is a strong case for the development of high-tech titanium product manufacturing in Ukraine, given the existing R&D advancements, particularly those from the G. V. Kurdyumov Institute for Metal Physics of the National Academy of Sciences of Ukraine. These developments have already led to the creation of an experimental base for titanium ingot processing

Table 1. **The Ratio of the Cost of 1 Ton of Export of Titanium Ores and Concentrates, Titanium Sponge and Titanium Products, as of 2021**

Product	The amount of titanium ore and concentrates for the production of 1 ton of products, t	Average cost of 1 ton of export, USD*	The ratio of the cost of 1 ton of export to the average value of the export of titanium ores and concentrates, times*	The ratio of the export value of 1 ton of certain types of products to the value of the required amount of titanium ores and concentrates for the production of 1 ton of products, times
Titanium ores and concentrates UKTZED261400	—	266	—	—
Titanium sponge	4.3	7304	27.5	6.4
HBI4 titanium products: profiles, wire, plates, sheets, tape, foil, pipes and tubes	6.6	24 578	92.4	14.0

* Calculations for the specified types are based on the yield coefficients for processing titanium ore into slag and subsequent products: 1 ton of ore → 0.7 tons of slag; 1 ton of slag → 0.33 tons of titanium sponge; 1 ton of titanium sponge → 0.93 tons of titanium ingots; 1 ton of titanium ingots → 0.7 tons of forgings, bars, etc.

Source: Calculated by the authors based on data from *Foreign Trade by Individual Types of Goods in the Countries of the World*, State Statistics Service of Ukraine, 2023. URL: https://www.ukrstst.gov.ua.

technologies, achieving world-record strength levels of up to 1,900 MPa.

Moreover, the Paton Electric Welding Institute of the National Academy of Sciences of Ukraine (IEW) has developed a line of industrial electron-beam installations with capacities ranging from 180 to 1,500 tons of titanium ingots per year. For instance, the UE5810 industrial electron-beam installation, equipped with seven Paton-300 electron guns with a total power of 2.5 MW, is capable of melting titanium ingots with a diameter of up to 1,100 mm and a weight of up to 20 tons.

These innovative developments mean that Ukraine now has the technological capability not only to produce titanium sponge, as it did previously, but also to produce titanium ingots and rolled products. This positions Ukraine to directly supply these high-value products to the U.S. and other international markets.

It is also noteworthy that, due to the advancements made by the Paton Electric Welding Institute of the National Academy of Sciences of Ukraine, it is economically more viable for Ukraine to focus on melting ingots with a diameter of up to 200 mm. By eliminating the costly reforging step from the technological process, Ukraine can then produce bars with a diameter of up to 60 mm. This approach not only reduces the final product cost by 10—15% but also makes these bars suitable for use in 3D printing.

The promising developments in additive technologies by the Paton Electric Welding Institute of the National Academy of Sciences of Ukraine offer the capability to produce parts with specific shapes and structures. Innovative technologies for the layer-by-layer production of titanium products through rapid prototyping have already been developed and proposed. These advancements open new possibilities for 3D printing parts for gas turbine engines in aircraft and the manufacturing of endoprostheses. Moreover, 3D printing technology will enable the production of items that are impossible to manufacture using conventional methods, giving Ukraine a competitive edge in international markets.

The advantages of these developments include the lower cost of the 3D printer compared to foreign counterparts, comprehensive research support and maintenance, and the use of domestic titanium raw materials and semi-finished products. Additionally, breakthroughs at the Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences of Ukraine in the field of new titanium alloys have made it possib-

Table 2. **Profitability (Loss) of the Operational Activities of Enterprises in 2017—2021,** %

Economic activities	Year				
	2017	2018	2019	2020	2021
Economy of Ukraine as a whole	8.8	8.1	10.2	6.2	12.6
Industry	6.8	6.3	5.5	3.9	11.2
Mining and quarrying	34.0	38.1	30.2	27.3	53.7
Extraction of metal ores	58.2	39.3	31.2	56.3	92.3
Mining of non-ferrous metal ores	25.6	10.2	–3.0	1.9	–0.4
Processing industry	4.6	3.6	3.4	4.4	9.0
Metallurgy	0.9	0.9	–7.7	0.9	16.0
Production of precious and other non-ferrous metals	4.0	0.7	0.8	3.3	1.8

Source: compiled by the authors based on the data of the State Statistics Service of Ukraine: Input-Output datasheets in basic prices for the corresponding years.

le to produce high-strength titanium alloys for structural applications.

All these factors indicate that Ukraine is technologically prepared to produce both metallic titanium and titanium-based products. Once production is established, these products could be supplied to global markets for use in the various industrial activities previously described.

Before the war, the main producer of titanium products in Ukraine was the Zaporizhzhia Titanium-Magnesium Plant (ZTMP). However, this plant is currently in a high-risk zone and may be at risk of destruction. Moreover, the plant is currently closed, highlighting the need to build new enterprises that can leverage innovative domestic technologies to produce metallic titanium and products, including those for military purposes — both for domestic use and export.

Our calculations indicate that constructing a new enterprise specializing in the production of metallic titanium and its products would potentially yield profitability that exceeds the current levels in the processing industry of other nonferrous metals several times (Table 2). Additionally, the added value generated would be twice as high compared to the pre-war figures recorded in the processing industry (Table 3).

Based on studies of the current state and assessments of the prerequisites and prospects for expanding the production of titanium products with a high added value, the feasibility of building a new factory for titanium product manufacturing on an innovative basis has been thoroughly considered and substantiated by the Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine.

This project will address the needs of the post-war economy, support the growing domestic market, and facilitate the entry of Ukrainian manufacturers into global markets, including the aerospace titanium sector. The factory's total annual design capacity is projected to be 22,000 tons, encompassing new titanium alloys with enhanced performance characteristics, titanium semi-finished products, and finished titanium goods.

The plant will employ cutting-edge technologies developed by the E. O. Paton Electric Welding Institute of the National Academy of Sciences of Ukraine, such as the production of 200 mm diameter rods using vacuum-arc remelting, additive manufacturing, and innovative layer-by-layer production techniques for titanium products, including parts for aircraft gas turbine engines.

The factory will produce a wide range of products, including titanium sponge, bars, profiles, wire, plates, tapes, foil, pipes, titanium ingots, and rolled titanium, all utilizing vacuum-arc remelting technology for the aerospace industry.

Table 3. **Share of Gross Added Value in Production (in basic prices) in 2017—2021, %**

Economic activities	Year				
	2017	2018	2019	2020	2021
Economy of Ukraine as a whole	40.2	40.3	40.9	41.7	41.1
Industry	25.5	25.9	22.8	25.6	26.6
Mining and quarrying	51.4	51.5	51.3	51.3	51.2
Extraction of metal ores, other minerals and development of quarries; provision of auxiliary services in the field of extraction industry	42.8	43.2	44.1	45.1	44.2
Processing industry	19.8	19.9	20.0	20.1	19.9
Metallurgy	14.5		14.3	15.2	15.4

Source: compiled by the authors based on the data of the State Statistics Service of Ukraine: Input-Output datasheets in basic prices for the corresponding years.

Additionally, it will manufacture products using 3D printing technology, such as turbines and components for mechanical engineering, shipbuilding, the medical industry, and construction.

This new factory is expected to create up to 3,500 high-quality jobs, offering competitive wages with an average salary of UAH 27,000 — nearly double the average monthly wage of full-time workers in the processing industry in 2021 (UAH 13,432). Salaries are anticipated to rise in line with inflation. Moreover, the factory will generate significant tax revenues for state and local budgets, including an estimated UAH 7.7 billion in personal income tax, UAH 9.4 billion in social security contributions, UAH 0.6 billion in military levies, UAH 34.9 billion in VAT, and UAH 28.4 billion in corporate income tax.

State support for this project is projected to amount to UAH 8.76 billion, or 30% of the total project cost. The overall investment required for constructing the new titanium production factory, based on innovative technologies, is estimated at UAH 29.2 billion, or USD 797.9 million. The structure of project financing is detailed in Table 4.

In order to increase the sources of funding for the project, it would be advisable to:

- **Expand State Participation:** Expand the state's participation in the implementation of such strategic projects, particularly by providing direct budget support in the form of innovative transfers, which would be subject to return to the budget after the implementation of investment projects. Alternatively, such transfers could involve allocating the state's share in the authorized capital of recipient enterprises. This approach is consistent with EU legislation in the field of state aid, particularly Regulation (EU) No. 1303/2013 of the European Parliament and the Council of December 17, 2013. Government participation in the capital of strategic enterprises in the titanium industry will contribute to the post-war recovery of the economy and ensure the stability of public finances in the medium term.
- **Introduce Financial Support for Investment Projects:** Introduce proper financial support for investment projects under the conditions of co-financing by the state, financial institutions, international organizations, enterprises, and the population, potentially through the issuance of bonds for the restoration and development of the titanium industry.

The project is an attractive investment for the state, domestic, and foreign investors in terms of

Table 4. **Investments by Sources of Project Funding and Stages, UAH million**

Source of funding	Structure of funding, %	1st stage		2nd stage 01.07.2026–01.07.2027	3rd stage 01.07.2027–01.07.2028	Total
		01.07.2024–01.07.2025	01.07.2025–01.07.2026			
Contributions to authorized fund of newly incorporated company, grants, financial investments	30	2 920.19	2 190.14	2 190.14	1 460.10	8 760.57
Borrowings, bank loans	40	3 893.59	2 920.19	2 920.19	1 946.79	11 680.76
Government support for projects with significant investments (tax benefits, exemption from import duty, reimbursement of construction costs for engineering and transport infrastructure facilities, insurance of direct investments against military risks)	30	876.06	1 752.11	3 504.23	2 628.17	8 760.57
Total	100	7 689.84	6 862.44	8 614.56	6 035.06	29 201.90

Source: prepared by the authors.

its prospects and profitability. According to our estimates, the net present value (NPV) for the minimum period of project implementation is UAH 11.38 billion, the internal rate of return is be 17%, and the investment profitability ratio is 1.51. The benefit-to-cost ratio (BCR) is estimated at 1.2, while the average Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA) during the investment period is equal to UAH 8.79 billion.

The availability of demand for titanium products in the medium term and the introduction of innovations will ensure the stability of income from its sale. The domestic market will be fully satisfied during the post-war recovery of the economy and its further expansion.

This project is an attractive investment considering the following factors: the availability of a sufficient raw material base within Ukraine; the prospects of the titanium industry in domestic and global markets; the availability of domestic innovative technologies and the significant R&D potential in Ukraine; educational programs for training personnel for the titanium industry; Ukraine's longstanding experience in manufacturing and exporting sponge titanium and semi-finished products; the country's proximity to EU countries and technical capabilities for transporting products to other countries; high profitability for investors; budgetary efficiency; significant tax revenues to state and local budgets; and the positive macroeconomic impact, which will be demonstrated below, contributing to the post-war recovery of the economy on an innovative basis.

An analysis of costs and benefits shows that the benefits outweigh the potential costs, especially when considering the project's purpose and its focus on addressing the strategic task of developing the titanium industry on an innovative basis.

Forecast figures regarding the increase in the production of metallic titanium and its products, based on the technical and economic justification of this unique innovative project for the development of the titanium industry, are provided in Table 5.

The positive macroeconomic impact and significant multiplier effects of this project have been demonstrated through the results of the calculations. As shown in Table 6, the multipliers of the increase in gross output of titanium and its products relative to the increase in the total goods and services output in Ukraine, as estimated by two different approaches, are quite close. This indicates both the validity of the estimates obtained and

Table 5. **Forecast of Growth in the Production (Output) of Metallic Titanium and Products Made of It in the First Year after the Implementation of the Investment Stage of the Project**

Product	Increase in the production (output), USD million	Production structure, %
Metallic titanium and products made of it, total	225.2	100.0
Including:		
titanium sponge	115.5	51.3
titanium products: rods, bars, profiles, wire, plates, tapes, foil	27.0	12.0
pipes, tubes, sheets and other titanium products	3.4	1.5
billets and products for the aviation industry	77.0	34.1
turbines, products for mechanical engineering, shipbuilding, medical industry, construction industry, etc. (using 3D technology)	2.5	1.1

Source: The authors' calculations based on data from the technical and economic feasibility study of the investment project for the development of metallic titanium production in Ukraine.

Table 6. **Multipliers of Increase in Gross Output and Gross Added Value for the Production of Metallic Titanium in the First Year Following the Implementation of the Project's Investment Stage**

Factor	Increase in employes salary neglected		Given increase employes salary	
	1st approach EA 25 Production of titanium and titanium products	2nd approach EA 24 Metallurgy	1st approach EA 25 Production of titanium and titanium products	2nd approach EA 24 Metallurgy
Multiplier effect of the increase in gross output of foreign trade on the increase in the total gross output of goods and services, times	2.2	2.4	2.71	2.99
Multiplier effect of the increase in the gross output of foreign trade on the increase in the total foreign trade in Ukraine (coefficient), times	0.73	0.6	0.87	0.59

Source: estimated by the author.

Table 7. **The Multiplier Effect for the Economy of Ukraine from the Growth of the Production of Metallic Titanium and Titanium Sponge in the First Year after the Implementation of the Investment Stage of the Project, Based on the First Approach**

Показники	Multiplication effect of the growth in the output, USD million	
	Increase in employes salary neglected	Given increase employes salary
The multiplier effect of the increase in the production of titanium and titanium products on the increase in the total gross output of goods and services in Ukraine	495.4	610.3
Including the effect of increasing the gross output of the titanium sponge	254.1	313.0
The multiplier effect of the increase in the gross output of titanium and titanium products on the increase in the total GVA in Ukraine	164.4	195.9
Including the effect of increasing the gross output of the titanium sponge	84.3	—

Source: estimated by the authors.

Table 8. **The Multiplier Effect for the Economy of Ukraine from the Growth of the Metallic Titanium Production, Based on the Second Approach**

Product	Multiplier effect from the growth in the output, USD million	
	The increase in wages of employees is not taken into consideration	Given the increase in wages of employees
Metallic titanium, total	540.42	562.7
Titanium sponge	277.2	—

Source: estimated by the author.

the effectiveness of the in-depth processing of titanium ore, aimed at forming a closed cycle for the production of metallic titanium and its products within Ukraine. The multiplier effect of developing the titanium industry in Ukraine is influenced by the structure of its production and the use of finished products, aligned with the technological stages of production and the directions of consumption in both domestic and foreign markets.

As shown in Tables 7—8, implementing an investment project focused on the production of metallic titanium and its products, compared to the effect of increasing the production of titanium sponge, significantly amplifies the impact. This effect nearly doubles, whether or not the increase in added value and wages of employees is considered.

Tables 6—8 present the results of calculations for output multipliers and added value associated with the production of metallic titanium in the first year following the implementation of the investment project. According to Table 7, the multiplicative effect of increasing the gross output of titanium and its products on the growth in the total VAT in Ukraine (considering the increase in employee wages) will amount to nearly USD 200 million in the first year of the project's operation. Our estimates suggest that this will contribute an additional 0.11—0.13 percentage points to Ukraine's GDP, with a cumulative increase of approximately 1.2—1.5 percentage points over the first ten years.

The scenario conditions for these calculations include:

- Rates of reduction in the cost of titanium and titanium products and increases in the share of added value in production due to the utilization of national technological assets.
- Growth rates for the titanium and titanium products, exports, and changes in the structure of titanium production and export (e.g., shifts in the ratio between titanium sponge and rolled steel).
- Dynamics of import substitution, focusing on:
  - Implementation of the state strategy for the development of the titanium industry, integrated into Ukraine's overall economic strategy.
  - Reduction in the cost of metallic titanium through technological innovations and changes in production and export structures.
  - Export of higher added value products: increased processing of titanium sponge in Ukraine and a corresponding rise in the production of finished titanium products.
  - Significant decrease in import intensity in the domestic market for metallic titanium and titanium products, positively impacting the foreign trade balance.

Future calculations can be conducted based on various scenarios, considering factors such as reductions in production costs, increases in the share of added value, production growth, export expansion, final consumption in the domestic market, and import substitution dynamics. These scenarios could be explored by dynamic models of interindustry balances.

CONCLUSIONS

1. The approaches used in the proposed study to assess the macroeconomic and multiplier effects of developing titanium production in Ukraine are based on the methodologies, techniques, and information provisions of macroeconomic models employed by scientists at the Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine. These models are used to forecast economic prospects and evaluate the consequences of investment policy implementation. The effectiveness of individual investment projects of national importance is calculated, which enhances the ability to substantiate investment priorities by considering the structural features of the national economy — factors that traditional methods might overlook. The determination of multiplier effects due to increased output and production for specific economic activities involves higher current production costs, which stimulate output growth in related economic activities. This, in turn, drives higher demand across a broader range of economic activities.

2. Multiplier effects related to the increase in Gross Value Added (GVA) arise from the creation of additional incomes for various economic entities (population, state, businesses) due to increased output. These additional incomes can translate into higher final consumer spending by households, increased state management expenditure, and greater gross accumulation of fixed capital. The resulting effects then propagate through the system of inter-industry connections.

3. The methodological approaches developed and implemented in this research can be used in the future for the comparative evaluation of state programs supporting various economic activities, as well as for large investment projects during and after wartime reconstruction.

4. Implementing a large investment project for the development of the titanium industry in Ukraine — considering the full production cycle and based on domestic R&D — will support the domestic industry during the post-war recovery and development period. Such a project will generate both direct and indirect effects by attracting investments for the construction of primary and related industries. This will stimulate production of both titanium products and auxiliary components, building materials, and revitalize logistics and transportation sectors, which will further drive employment and wage growth.

5. The commissioning of the new titanium plant under the proposed project will generate commercial efficiency for both private and state investors. If the state acts as an investor, it will also achieve additional budget efficiency. Additionally, the demand for materials and components needed for construction will stimulate business activity, creating multiplier effects both during the investment phase and throughout the plant's operation. The project will generate up to 3,500 jobs, which is crucial for providing employment opportunities as demobilized personnel return.

6. The project's implementation will reduce Ukraine's import dependence by improving domestic production of metallic titanium and related products that were previously imported. It will also enhance Ukraine's export capacity by supplying products with a higher specific weight of added value to international markets, thus integrating Ukraine into the global value chain.

7. Developing a complete closed cycle for the production of metallic titanium and its products will necessitate state policies that stimulate investment activities by creating favorable conditions for both domestic and foreign investors. The results of the multiplier effects and the projected increase in gross added value highlight the potential for increased budget revenues, particularly as production transitions from titanium sponge to metallic titanium and its products. The anticipated increase in GVA from this production expansion provides a strong basis for the state to offer preferential investment conditions and support the development of a closed production cycle for metallic titanium and its products.

8. The implementation of innovative projects impacts not only the country's economy but also its social policy. There is a direct relationship between the growth of gross added value and the income level of the population. This means that numerical methods can be used to calculate the indirect effects on the relationship between consumption and income, as well as the effects on employment growth in other economic sectors. Such assessments enable the consideration of social factors when planning development and formulating target programs for emerging industries.

9. Determining the multiplier effects for the economy due to an increase in output or production for a specific type of economic activity involves an increase in current production costs, which stimulates output growth in related economic activities. This, in turn, drives increased demand for products across a broader range of economic activities.

10. On one hand, the calculated multiplier effects from output and wage growth in the studied foreign trade enterprises should not be compared directly with the scale of the overall economy due to their typically minor impact on its structure.

On the other hand, these multiplier effects create additional demand for domestic manufacturers' products, which can be met by increasing production capacities and utilizing accumulated stocks. The rise in demand for domestic products also generates a need for labor.

11. In the medium term, with a focus on export-oriented development of the titanium industry, Ukraine will not fully realize its existing raw material and technological potential. Long-term realization depends on significant growth in sectors that consume titanium products. Additionally, increased titanium production can have a positive macroeconomic effect not only in industrial production but also on the overall Ukrainian economy.

12. It is quantitatively demonstrated that the growth in metallic titanium production from the proposed investment project will significantly impact the economy. Specifically, it can contribute an additional average annual GDP growth of 0.11—0.13 percent, and cumulatively for the first ten years, the contribution to domestic GDP dynamics will be approximately 1.2—1.5 percentage points.

REFERENCES

1. On the decision of the National Security and Defense Council of Ukraine dated July 16, 2021 "On stimulating the search for, extraction and beneficiation of minerals that are of strategic importance for the sustainable development of the economy and defense capability of the state": Decree of the President of Ukraine of 23.07.2021 No. 306/2021. *Official site of Verkhovna Rada of Ukraine* (2021). URL: https://zakon.rada.gov.ua/laws/show/306/2021#Text (Last accessed: 18.04.2023).
2. On the approval of the list of subsoil areas (mineral deposits) that are of strategic importance for the sustainable development of the economy and defense capability of the state, which will be made available for use through tenders for the conclusion of production sharing agreements: Resolution of the Cabinet of Ministers of Ukraine of 14.02.2023 No. 132. *Official site of Verkhovna Rada of Ukraine* (2023). URL: https://zakon.rada.gov.ua/laws/show/132-2023-%D0%BF#Text (Last accessed: 20.08.2023).
3. U.S. Geological Survey. (2022). Mineral commodity summaries 2022. U.S. Geological Survey. https://doi.org/10.3133/mcs2022
4. Shelementieva, T. V. (2012). Increase of efficiency of industrial production for account of decline of unit cost. *Economy and enterprise,* 4(67), 146—152. URL: http://www.econom.stateandregions.zp.ua/journal/2012/4_2012/29.pdf [in Ukrainian].
5. Roux, R. N., Van Der Lingen, E., Botha, A. P., Botes, A. E. (2020). The fragmented nature of the titanium metal value chain. *J. S. Afr. Inst. Min. Metall,* 120(11), 633—640. http://dx.doi.org/10.17159/2411-9717/1126/2020.
6. Kahn, R. F. (2011). *The making of Keynes' general theory*. Published by Cambridge University Press, Cambridge (1984). URL: https://www.abebooks.co.uk/9780521253734/Making-Keynes-General-Theory-Raffaele-052125373X/plp (Last accessed: 18.04.2023).
7. Keynes, J. M. (1937). The General Theory of Employment. *The Quarterly Journal of Economics.* URL: https://macroeconomiauca.wordpress.com/wp-content/uploads/2012/05/keynes_general_theory_of_employment_qje_1937.pdf (Last accessed: 19.04.2023).
8. Samuelson, P. A. (1948). *Economics, an Introductory Analysis.* McGraw-Hill Book Company.
9. Sholomytskyi, Yu., Deisan, I., Sholomytska, O., Onopriienko, A., Shapoval, N. (2021). Assessment of the economic effects of the "Major construction" program in 2020—2023. URL: https://kse.ua/wp-content/uploads/2021/02/GC_roads_construction_impact_final_compressed-1.pdf (Last accessed: 27.05.2023) [in Ukrainian].
10. Kolosinska, M., Boyda, S. (2021). Multiplicative effect tourism industry. *Efficient economy*, 1. https://doi.org/10.32702/2307-2105-2021.1.79 [in Ukrainian].
11. Skrypnychenko, M. I., Kuznietsova, L. I., Bilotserkivets, O. H. (2022). Scenario based macro assessments of the post-war recovery of Ukraine's economy. *Economics and Forecasting*, 3, 48—74. https://doi.org/ 10.15407/econforecast2022.03.019 [in Ukrainian].
12. Lytvynenko, K. O. (2016). Multiplicative model of the investment impact on the business sector (commercial real estate case). *Investment: practice and experience,* 16, 41—45 [in Ukrainian].
13. Nykyforuk, O. I., Kucher, S. V., Stasyuk, O. M., Fediai, N. O. (2023). Multiplication effects of investment in a publicly significant infrastructure project. *Economy and Forecasting,* 1, 97—114. https://doi.org/10.15407/eip2023.01.097 [in Ukrainian].

14. Omelchuk, V. O. (2010). Multiplicative macro-effects of investments in residential construction. *Investment: practice and experience,* 19, 11—16. URL: http://www.investplan.com.ua/pdf/19_2010/5.pdf (Last accessed: 11.02.2023) [in Ukrainian].
15. Odintsov, O. M. (2015). Multiplicative effect of increasing internal reserves of agricultural production. *Economy AIC*, 3, 34—38 [in Ukrainian].
16. Shyrokova, O. M., Cheliadinova, N. H. (2012). Multiplicative effect from railway transport activities. *Bulletin of transport economics and industry*, 40, 79—82 [in Ukrainian].
17. Bida, M. (2013). The calculation of the foreign trade multiplier for the countries of central and estern europe. *Visnyk of the Lviv University. Series International Relations*, 33, 239—247 [in Ukrainian].
18. Prokopov, O. A. (2011). The multiplier effect of the competitiveness of the national economy on the international market of information services. *Economic bulletin of NTUU "KPI"*. URL: https://economy.kpi.ua/uk/node/265 (Last accessed: 03.10.2022) [in Ukrainian].
19. Shadura-Nykyporetc, N. T., Minenko, O. V. (2014). The use of multiplicative models for the study of the conditions of regional economic system. *Odesa National University Herald. Series Economy,* 19(2/6), 204—208. URL: http://visnyk-onu.od.ua/journal/2014_19_2_6/46.pdf (Last accessed: 17.04.2023) [in Ukrainian].
20. Doroshkevych, D. V. (2011). Use expansion coefficients for the management of investment processes in the regional systems. *Efficient economy*, 3. URL: http://www.economy.nayka.com.ua/?op=1&z=3280 (Last accessed: 18.01.2024) [in Ukrainian].
21. The influence of the nuclear energy complex on the development of Ukraine. (2019). *Analytical report: Ukrainian nuclear forum. Ukrainian Nuclear Society,* 27. URL: https://ukrns.org/images/activity/2019/2019_09_25/analitychnyzvit.pdf (Last accessed: 13.09.2023) [in Ukrainian].
22. Chepeliev, M. H. (2012). Evaluation of multiplier effects for the branches of the economy of Ukraine: a retrospective analysis based on "expenditure-output" tables. *Ekonomist,* 11, 74—76 [in Ukrainian].
23. Horobinska, I. V. (2012). The formation of cross-industry multiplier effects in the economy as a result of the reduction of tariffs for transport services. *Visnyk of Chernihiv State Technological University. Series Economics,* 3(60), 185—189 [in Ukrainian].
24. Methodological regulations on the organization of state statistical observation "Expenditure-output table": Order of State Statistics Service of Ukraine of 01.11.2018 No. 236. *State Statistics Service of Ukraine*. URL: http://www.ukrstat.gov.ua/metod_polog/metod_doc/2018/236/mp_tvv.pdf (Last accessed: 10.03.2023) [in Ukrainian].
25. Regulation (EU) No. 1303/2013 of the European Parliament and of the Council of 17 December 2013. URL: http://data.europa.eu/eli/reg/2013/1303/oj (Last accessed: 18.11.2023).
26. Regulations Commission Implementing Regulation (EU) 2015/207 of 20 January 2015. *Official Journal of the European Union*. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R0207&from=EN (Last accessed: 12.01.2024).
27. Regulation (EU) 2021/1060 of the European Parliament and of the Council of 24 June 2021. URL: http://data.europa.eu/eli/reg/2021/1060/oj (Last accessed: 12.01.2024).
28. Economic Appraisal Vademecum 2021—2027 (2021). General Principles and Sector Applications. *Official site of the European Commission*. URL: https://ec.europa.eu/regional_policy/en/information/publications/guides/2021/economic-appraisal-vademecum-2021-2027-general-principles-and-sector-applications (Last accessed: 22.12.2023).
29. The Economic Appraisal of Investment Projects at the EIB — 2nd Edition (2023). *Official site of the European Investment Bank*. March. URL: https://www.eib.org/en/publications/20220169-the-economic-appraisal-of-investment-projects-at-the-eib (Last accessed: 15.09.2023).
30. Odintsov, M. M., Odintsov, O. M. (2011). Multiplicative impact of investments on the effectiveness of the development of the region. *Investment: practice and experience,* 9, 4—6 [in Ukrainian].
31. Suchkov, A. V. (2009). Using the multiplicative method of evaluating the efficiency of investments in franchising. *Herald of Khmelnytskyi National University. Economic sciences,* 4(3), 129—133. URL: http://journals.khnu.km.ua/vestnik/pdf/ekon/2009_4_3/pdf/129—133.pdf (Last accessed: 17.08.2023) [in Ukrainian].
32. Ďurčová, J. (2018). Gains from Export. *Journal of Applied Economic Sciences*, XII, 1(23), 105—113. URL: https://www.researchgate.net/publication/327688559_Gains_from_export_-_the_input_output_approach (Last accessed: 18.04.2023).
33. Lima, J. E. D., Banacloche, S. (2022). Economic analysis based on input-output tables. Definitions, indicators and applications for Latin America. *United Nations publication*. URL: https://repositorio.cepal.org/server/api/core/bitstreams/bcf53eb1-35e5-49b1-8616-1683b9aefb6d/content (Last accessed: 16.05.2023).

34. D'Hernoncourt, J., Cordier, M., Hadley, D. (2011). Input-Output Multipliers — Specification sheet and supporting material, Spicosa Project Report. *Université Libre de Bruxelles — CEESE. Brussels.* URL: https://www.researchgate.net/publication/351821039_Input-Output_Multipliers_-_Specification_sheet_and_supporting_material_Spicosa_project_report (Last accessed: 27.05.2023).
35. Pistun, T. T. (2014). Assessment of Multiplicative Effects in the Context of Analyzing the Impact of Tax Policy on Macroeconomic Processes. *Business Inform*, 8, 247—252. URL: https://www.business-inform.net/export_pdf/business-inform-2014-8_0-pages-247_252.pdf (Last accessed: 11.07.2023) [in Ukrainian].
36. Nugroho, Y., Murti, S. (2020). Analysis of Input-Output Table : Integrated of Economic Development by Leading Sectors in Indonesia. *2020 Asia-Pacific Statistics Week A decade of action for the 2030 Agenda: Statistics that leaves no one and nowhere behind*. Bangkok, Thailand. URL: https://www.unescap.org/sites/default/files/APS2020/77_Analysis_of_Input-Output_Table_Integrated_of_Economic_Development_by_Leading_Sectors_in_Indonesia.pdf (Last accessed: 18.09.2023).
37. Hoff, P. (2021). Additive and Multiplicative Effects Network Models. *Statistical Science, Statist. Sci.,* 36(1), 34—50. URL: https://projecteuclid.org/journals/statistical-science/volume-36/issue-1/Additive-and-Multiplicative-Effects-Network-Models/10.1214/19-STS757.full?tab=ArticleLink (February 2021) (Last accessed: 28.07.2023).
38. Cai, J. N., Huang, H., Leung, P. S. (2019). Understanding and measuring the contribution of aquaculture and fisheries to gross domestic product (GDP). *FAO Fisheries and Aquaculture Technical Paper*. No. 606. Rome, FAO. 80 pp. URL: https://www.researchgate.net/publication/335220091_Understanding_and_measuring_the_contribution_of_aquaculture_and_fisheries_to_gross_domestic_product_GDP (Last accessed: 18.02.2024).
39. Markovskyi, P. E. Savvakin, D. G. (2021). An outstanding personality of titanium science. To the 75th anniversary of Academician of the National Academy of Sciences of Ukraine O.M. Ivasyshyn. *Bulletin of the National Academy of Sciences of Ukraine*, 11, 84—89. https://doi.org/10.15407/visn2021.11.084 [in Ukrainian]
40. Akhonin, S. V. (2019). Trends in the development of special electrometallurgy of titanium in Ukraine. *Bulletin of the National Academy of Sciences of Ukraine*, 6, 28—36. https://doi.org/10.15407/visn2019.06.028 [in Ukrainian]
41. Karpets, M. V., Firstov, S. O., Rokytska, O. A., Krapyvka, N. A. (2016). The effect of titanium on the phase composition of alloys of the Ti—Cr—Al—Si—O system. *International scientific conference "Materials for work in extreme conditions — 6" (December 1—2, 2016, Kyiv)*. Kyiv, 309—312. URL: http://surl.li/jvdut (Last accessed: 10.05.2023) [in Ukrainian].
42. Firstov, S. A. (2004). The main tendencies in elaboration of materials with high specific strength. In: *Metallic materials with high structural efficiency,* 33—44. Dordrecht [in Ukrainian].
43. Regulation (EU) No 1303/2013 of the European Parliament and of the Council of 17 December 2013. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32013R1303 (Last accessed: 18.01.2024).

Received 16.04.2024
Revised 03.06.2024
Accepted 11.06.2024

М.І. Скрипниченко (https://orcid.org/0000-0003-3804-9857),
О.І. Никифорук (https://orcid.org/0000-0001-7376-3373),
О.С. Білоусова (https://orcid.org/0000-0001-7434-3469),
О.М. Стасюк (https://orcid.org/0000-0002-4701-5598),
Н.О. Федяй (https://orcid.org/0000-0002-6529-1078),
О.Г. Білоцерківець (https://orcid.org/0000-0003-0051-2877),
Л.І. Кузнєцова (https://orcid.org/0000-0001-8711-7487)

Інститут економіки та прогнозування Національної академії наук України,
вул. Панаса Мирного, 26, Київ, 01011, Україна,
+380 44 280 1234, gvm@ief.org.ua

ІНВЕСТИЦІЙНА ПРИВАБЛИВІСТЬ ТА МУЛЬТИПЛІКАЦІЙНІ ЕФЕКТИ ДЛЯ НАЦІОНАЛЬНОЇ ЕКОНОМІКИ ВІД РОЗВИТКУ ТИТАНОВОЇ ГАЛУЗІ

Вступ. Розвиток титанового виробництва в Україні шляхом створення повного циклу виробництва має стати пріоритетним у політиці розвитку стратегічних видів діяльності та відповідати національним інтересам в економіці країни.

Проблематика. Забезпечення внутрішніх потреб у металевому титані та нарощення його експорту у перспективі потребує розвитку високотехнологічної промисловості, зокрема випуску готових виробів з металевого титану. Важливим при цьому є розрахунок макроекономічних ефектів розвитку титанового виробництва.

Мета. Обгрунтувати привабливість проєктів для інвесторів та оцінити макроекономічні мультиплікаційні ефекти від розвитку титанового виробництва в Україні у напрямку поглибленої переробки сировини і виготовлення готової продукції.

Матеріали й методи. Основою дослідження є побудова системи збалансованих показників оцінки привабливості інвестпроєкту для держави, внутрішніх і зовнішніх інвесторів. Розрахунки мультиплікаційних ефектів для економіки здійснено на основі таблиці «Витрати-випуск» в основних цінах через прирости валового випуску та валової доданої вартості для виду економічної діяльності.

Результати. Проведено багатоетапне дослідження інвестиційного проєкту будівництва нового титанового заводу та впливу розвитку титанової галузі на економіку України за розрахунками мультиплікаційних ефектів національної значимості. Показано методологічні підходи, які доцільні й для інших стратегічно важливих перспективних видів промисловості у повоєнний час.

Висновки. Розвиток повного замкнутого циклу з виробництва металевого титану та виробів з нього вимагатиме формування державної політики стимулювання інвесторів у частині формування пільгових умов їхньої діяльності. На це вказують отримані оцінки привабливості титанового інвестпроєкту, результати мультиплікаційних ефектів приросту валового випуску та масштабів очікуваного приросту валової доданої вартості, зокрема при переході від випуску титанової губки до виробництва готових титанових виробів.

Ключові слова: титанова галузь, інвестиції, виробництво повного циклу, інвестиційний проєкт, мультиплікаційні ефекти, приріст валового випуску, валова додана вартість, таблиця «витрати-випуск», сценарні розрахунки.