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TRANSFORMATION OF THE DEVELOPMENT STRATEGY OF HIGH-TECHNOLOGICAL PRODUCTION SYSTEMS

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ABSTRACT

In the article, the features of the formation and development of high-tech production systems in countries with different levels of economic development are examined. The purpose of the study is a comprehensive analysis of the prerequisites, structure and results of the functioning of high-tech production systems in countries with different levels of economic development based on a system of indicators of innovative activity, human capital, high-tech production and international trade in high-tech products, as well as substantiation of the directions of transformation of strategies for the development of high-tech production systems in modern conditions of global economic competition. The methodological basis of the study is the methods of theoretical generalization, statistical and comparative analysis, correlation analysis and conceptual modeling. The empirical basis of the study was formed based on the analysis of indicators of research and development costs, employment in knowledge-intensive types of economic activity, the share of high-tech production, as well as indicators of import, export and trade balance of high-tech products in Sweden, Romania, Ukraine and the Republic of Moldova for 2020–2025. It was found in the study that countries with a high level of investment in scientific research and development and a significant share of employment in knowledge-intensive sectors demonstrate a more developed structure of high-tech production and higher competitiveness in international markets for high-tech products. It was found that Sweden is characterized by a balanced structure of high-tech trade and a high level of innovative activity, while Romania is characterized by positive dynamics of development of high-tech production, which gradually strengthens its export potential. In contrast, Ukraine and the Republic of Moldova demonstrate significant dependence on imports of high-tech products, which indicates limited domestic production and innovation potential in the relevant segment. The correlation analysis confirmed the presence of a close relationship between investments in scientific research, development of human capital and the results of functioning of high-tech production. Based on the integrated analysis, a conceptual model of the transformation of the development strategy of high-tech production systems was formed, which reflects the logical transition from the formation of innovative resources to ensuring production results and strengthening the country's competitiveness in international trade in high-tech products. The practical effect of the study is the possibility of using the obtained results to form an effective state policy to support innovative development, stimulate investment in scientific research and the development of high-tech production, as well as develop strategies to increase the technological competitiveness of countries with transformational economies.

Keywords: *High-Tech Production, Innovative Development, Scientific Research And Development, Knowledge-Intensive Industry, International Trade In High-Tech Products, Economic Competitiveness.*

1. INTRODUCTION

In today's conditions of global technological competition and accelerated digital transformation of the economy, the development of high-tech production systems is becoming key to ensuring

long-term economic growth, increasing the competitiveness of national economies and forming stable positions of states in global value chains. It is high-tech industries that ensure the generation of innovations, the creation of products with a high share of added value, the creation of new jobs in the knowledge economy and the strengthening of the export potential of countries.

The formation of effective high-tech production systems is a complex multifactorial process that depends on the development level of scientific and research potential, the volume of investments in research and development, the structure of employment in knowledge-intensive sectors of the economy, the level of development of industrial production and the country's integration into international trade in high-tech products. The interaction of these factors forms the country's innovative potential and determines its capabilities for the creation, commercialization and export of high-tech products.

Research into the development of high-tech production systems is of particular relevance for countries with transformational economies that seek to strengthen their own technological capabilities and integrate into global innovation processes. For these states, it is important not only to increase scientific potential, but also to form an effective production structure and foreign economic relations that contribute to the development of high-tech sectors of the economy.

Taking into account the above, it is relevant to study the potential of countries to form competitive high-tech production systems and to substantiate the directions of transformation of their development strategies in the context of modern global economic changes.

2. LITERATURE REVIEW

In modern scientific literature, the development of high-tech sectors is considered as one of the key factors in ensuring long-term economic growth, structural modernization of the economy and increasing the international competitiveness of states [2; 14; 33]. It is high-tech industries that form the basis of the knowledge economy, ensure the creation of products with a high share of added value and act as a source of technological innovations that transform traditional production systems [40; 52].

Fundamental approaches to defining high-tech sectors of the economy were formed in the works of Hatzichronoglou [22], who proposed a methodology for classifying industries by the level of technological intensity based on the share of research and development (R&D) expenditures. The proposed methodology became the basis of modern statistical approaches to the analysis of high-tech production and is widely used in studies based on OECD and Eurostat statistical data [12; 22; 41; 54].

Further development of research in this area is associated with the analysis of the role of innovation in shaping the technological competitiveness of economies. A significant number of studies [13; 60; 62] confirm that investment in research and development is one of the key drivers of economic growth. In particular, the study by Falk [13] shows that an increase in the share of R&D spending in the structure of the economy has a positive long-term impact on labor productivity, economic growth rates and the development of high-tech industries. Similar results were obtained in the works of Wang et al. [59; 60]who prove that the effectiveness of investment in research largely depends on the development level of innovation infrastructure and institutional environment.

A separate area of scientific research [7; 26; 34] is devoted to the role of human capital in the formation of high-tech production systems. Within the framework of the concept of the knowledge economy, it is emphasized that the concentration of highly skilled labor, scientific institutions and innovative enterprises creates a technological spillover effect that stimulates the development of innovation clusters and accelerates the technological modernization of the economy. In this context, Wang's research et al. [59] demonstrate that agglomerations of high-tech enterprises contribute to the formation of innovation ecosystems that ensure faster commercialization of scientific developments.

Considerable attention in the modern economic literature [6; 27; 54] is also paid to the relationship between the development of high-tech production and the structure of international trade. The share of high-tech exports is widely used as an indicator of a country's technological competitiveness and its ability to integrate into global value chains. In particular, the study of Zapata et al. [63] show that the growth of high-tech exports has a positive effect on economic growth and contributes to the increase in economic productivity. Similar results were obtained in the works of Şahin [47] and Şahin [65], which confirm the hypothesis of export-oriented economic growth in countries with a high level of development of technological industries.

Other studies emphasize the importance of analyzing the structure of high-tech trade for assessing the innovation potential of an economy. In particular, Kalyuzhna and Dashkov [28] note that the structure of high-tech exports reflects the ability of

the economy to generate technological innovations and commercialize them in international markets. In turn, Makarenko et al. [37] prove that the dynamics of exports of high-tech products has a significant impact on the rate of economic growth and can act as an indicator of technological modernization of the national economy.

Despite the significant amount of research devoted to the development of high-tech sectors [11; 34; 52], a number of debatable issues remain in the scientific literature regarding the relationship between the resource base of innovative development, the structure of production and the results of international trade in high-tech products. Most of the existing research [3; 4; 7; 21] focuses on the analysis of individual factors of innovative development, including investment in research and development or export of high-tech products, while a comprehensive analysis of the interaction of financial, personnel and production components of high-tech production systems remains insufficiently studied.

In addition, in modern studies [25; 30; 32; 61] insufficient attention is paid to the comparative analysis of countries with different levels of economic and innovative development, which limits the possibilities of identifying patterns in the formation of high-tech production systems in transformational economies. That is why it is relevant to conduct a comprehensive comparative analysis that allows assessing the relationship between investments in scientific research, human capital development, the structure of high-tech production and the results of international trade in technological products [6; 18; 33; 36].

In view of the above, this study is aimed at a comprehensive analysis of the prerequisites for the formation and results of the functioning of high-tech production systems in countries with different levels of economic development. Particular attention is paid to the study of the relationship between investment in research and development, human capital development, the share of high-tech production and indicators of international trade in high-tech products.

Despite the significant number of studies devoted to the development of high-tech sectors [11; 34; 52], a number of debatable issues remain in the scientific literature regarding the relationship between the resource base of innovative development, the structure of production and the results of international trade in high-tech products. Most of the available studies [3; 4; 7; 21] focus on the analysis of individual factors of innovative development, in particular investments in scientific research and development or exports of high-tech products, while a comprehensive analysis of the interaction of financial, personnel and production components of high-tech production systems remains insufficiently studied.

In addition, in modern studies [25; 30; 32; 61] insufficient attention is paid to the comparative analysis of countries with different levels of economic and innovative development, which limits the possibilities of identifying patterns of formation of high-tech production systems in transformation economies. This necessitates the need for a comprehensive study that would integrate the analysis of R&D investments, human capital, production structure and foreign trade indicators into a single analytical system [6; 18; 33; 36].

Therefore, the scientific problem of the study lies in the insufficient development of a comprehensive approach to assessing the formation and functioning of high-tech production systems, which would take into account the relationship between innovative resources (R&D), human capital (knowledge employment), production structure (high-tech manufacturing) and the results of integration into global markets (high-tech trade), especially in the conditions of countries with different levels of economic development.

That is, there is a statistically significant and stable relationship between the volume of investment in scientific research and development, the level of human capital development and the share of high-tech production, which, in turn, determines the competitiveness of the country in international markets for high-tech products; the strength and nature of this relationship vary significantly depending on the level of economic development of the country.

Thus, this study is aimed at overcoming the above-mentioned scientific gaps by conducting a comprehensive comparative analysis, which allows not only to identify key patterns in the development of high-tech production systems, but also to substantiate the directions of transformation of their development strategies in the modern conditions of the global economy.

The purpose of the study is a comprehensive analysis of the prerequisites, structure and results of the functioning of high-tech production systems in countries with different levels of economic development based on a system of indicators of innovative activity, human capital, high-tech production and international trade in high-tech products, as well as substantiation of the directions of transformation of strategies for the development

of high-tech production systems in modern conditions of global economic competition.

3. METHODOLOGY

The methodological basis of the study is a systematic approach to the analysis of the development of high-tech production systems, which involves a comprehensive combination of theoretical and empirical research methods. This approach allows us to consider high-tech production as a complex multi-level system, the functioning of which is determined by the interaction of scientific potential, human capital, production structure and foreign economic activity. The research methodology includes the following stages:

1. Using methods of theoretical generalization, analysis and systematization of scientific sources, the economic essence of high-tech production has been clarified and key approaches to the classification of high-tech goods and industries have been identified. Based on the analysis of international methodologies (in particular, the OECD and Eurostat approaches), a system of indicators has been formed that characterize the level of development of high-tech production systems.

2. An analytical system of indicators has been formed that reflect the main components of the functioning of the high-tech economy. Gross expenditure on R&D, knowledge-intensive employment, high-tech manufacturing. To assess the foreign economic results of the functioning of high-tech sectors, high-tech imports less re-imports, high-tech exports less re-exports and trade balance in the high-tech products segment.

3. The use of statistical and comparative analysis methods made it possible to assess the dynamics of the indicated indicators by country (Sweden, Romania, Ukraine, Republic of Moldova) during 2020–2025.

4. Using the correlation analysis method, the relationship between key components of the high-tech production system of countries was determined, in particular between R&D spending, employment in knowledge-intensive sectors, and the share of high-tech production.

5. Using the methods of logical generalization and conceptual modeling, an integrated model of transformation of the development strategy of high-tech production systems was formed.

Thus, the application of a comprehensive methodological approach, combining theoretical analysis, statistical methods, the correlation analysis and conceptual modeling, made it possible to comprehensively investigate the conditions of formation, results of functioning and directions of transformation of development strategies of high-tech production systems.

Within the framework of the study, four countries were selected for a comparative analysis of the development of high-tech production systems, namely: Sweden, Ukraine, Romania and Moldova. The choice of these countries is due to their different levels of innovative and economic development, which allows for a comprehensive comparison of the structural prerequisites for the formation of high-tech production.

In particular, Sweden belongs to the group of leading innovative economies in Europe and ranks first among the countries of the European Union in terms of the level of innovative development according to Global Innovation Index and European Innovation Scoreboard, showing indicators that are significantly higher than the EU average. Sweden also belongs to the group of high - income countries.

To ensure a correct comparison, the sample includes neighboring countries of Ukraine, which occupy different positions in international rankings of innovation and economic development. In particular, Romania in a number of international rankings of innovation development demonstrates higher positions compared to Ukraine, which allows us to consider it as an example of a country with a higher integration level into the European innovation space. At the same time, Moldova is characterized by lower indicators of innovation development, which makes it a relevant object for comparison with countries with limited innovation resources.

In addition, the countries studied belong to different groups in terms of the level of economic development in the World Bank classification, which provides the opportunity to analyze the impact of income levels on the formation of high-tech production systems. Thus, Sweden belongs to the high-income category economies, Romania - to upper middle-income economies, while Ukraine and Moldova during the studied period 2020–2025 belong to the lower group middle-income economies with transition to upper group middle-income. This differentiation allows us to trace how the level of economic development of a country affects the formation of innovative potential, the structure of high-tech production, and the results of international trade in high-tech products.

As a result, the formed sample of countries provides the possibility of multi-level comparative analysis, which allows us to identify the patterns of formation of high-tech production systems in countries with different levels of economic development and innovation potential.

4. RESULTS

In the current conditions of global technological transformation of production, there is a significant change in approaches to the formation of strategies for the development of high-tech production systems. The development of digital technologies, the spread of the concepts of "smart production" and the transition to the Industry 4.0 paradigm leads to the integration of innovations into production processes. This allows the formation of intelligent production environments in which equipment and management systems provide flexibility, adaptability and high production efficiency.

The formation of the modern classification of high-tech goods is associated with the research of Hatzichronoglou, who in 1997 published an analytical work "Revision of the High Technology Sector and Product Classification" [22]. This work developed a methodological approach to determining the technological intensity of industries, which later became one of the key standards of international statistics on innovative development and industrial structure. Hatzichronoglou [22] argued that it is appropriate to assess the technological intensity of industries through the intensity of research and development (R&D) expenditures in combination with the embodied technology, that is, innovations that are integrated using intermediate goods and technological equipment. It is this approach that has become the basis of international statistics of innovative development and analysis of high-tech sectors of the economy. The methodology involves dividing industries into four groups depending on the level of technological intensity: high-technology, medium-high-technology, medium-low-technology and low-technology.

Under the concept of embodied technology refers to technological knowledge and innovations that the industry receives indirectly – through the purchase of high-tech equipment, components or intermediate products that contain a significant intellectual component.

Based on this methodology, a list of high-tech goods was formed, which was used in statistical studies of international trade. The main groups of high-tech products according to the OECD 1997 classification included: radioactive materials, electron lamps and tubes, other electronic equipment, aircraft and their components, optical instruments, measuring and control instruments, photographic equipment, film and photographic materials, optical fibers and products made of them, pharmaceutical products, medicinal products, office machines and computers, telecommunications equipment and other electronics. Later, this system was developed and adapted for the needs of international trade statistics within the framework of cooperation between the OECD and Eurostat.

International trade classification. Trade Classification [54]. Within the framework of this methodology, nine aggregated groups of high-tech products are distinguished: aerospace; computers and office machines; electronics and telecommunications; pharmaceuticals; scientific instruments; electrical machinery; chemistry; non-electrical machinery; armament [54].

However, subsequent statistical revisions have updated the methodological basis of the classification. Since the mid-2010s, international statistics have gradually switched to using the International Standard Industrial Classifications. Classification [27] and Statistical Classification of Economic Activities in the European Community [12]. Within this new taxonomy, the assessment of the technological sophistication of industries is based primarily on the direct intensity of research and development spending, which provides a more unified approach to international statistical comparisons.

Thus, the methodology proposed by Hatzichronoglou [22] laid the foundation for modern approaches to defining high-tech goods and industries, allowed the formation of an internationally recognized system for classifying the technological intensity of the economy, and became an important tool for analyzing innovative development, industrial structure, and international trade in high-tech products.

The importance of the high-tech sector for economic growth is confirmed by a number of empirical studies. In particular, Falk [13] proves that an increase in the share of R&D investment in high-tech industries has a long-term positive impact on GDP per capita and labor productivity. The analysis of data from OECD countries has shown that the structure of investment in research and development is no less important than their total volume.

Similar results were obtained by Wang et al. [60], who prove that research spending in the high-tech sector has the strongest positive effect in high-income countries, since they have better developed innovation infrastructure and mechanisms for technology commercialization.

Thus, studies of global technology-intensive industries emphasize that the high-tech sector makes a significant contribution to the formation of benefit and growth of the national GDP, since it is these

industries that provide the largest technological multiplier in production chains.

An important aspect of the development of the high-tech industry is also the functioning of the entire high-tech production system of countries.

In particular, C. Wang et al. [59], studying agglomerations of high-tech industry, show that the concentration of highly skilled labor, innovative infrastructure, and investments in science creates the effect of technological diffusion between regions, which accelerates the development of the high-tech sector.

Karahan [29] proves that the intensity of enterprises' R&D expenditures is a key factor in the transition of traditional industries to high-tech production, which is accompanied by an increase in productivity and innovative activity of enterprises.

Thus, the results of scientific research indicate that the high-tech sector of the economy is formed on the basis of high intensity of research and development, significant concentration of intellectual capital and active use of innovative technologies. It is these industries that ensure the acceleration of economic growth, increase in labor productivity and the formation of competitive advantages of national economies in the global technological environment.

That is, a high-tech production system is a complex of interconnected elements, where knowledge is transformed into technology, and technology into competitive products.

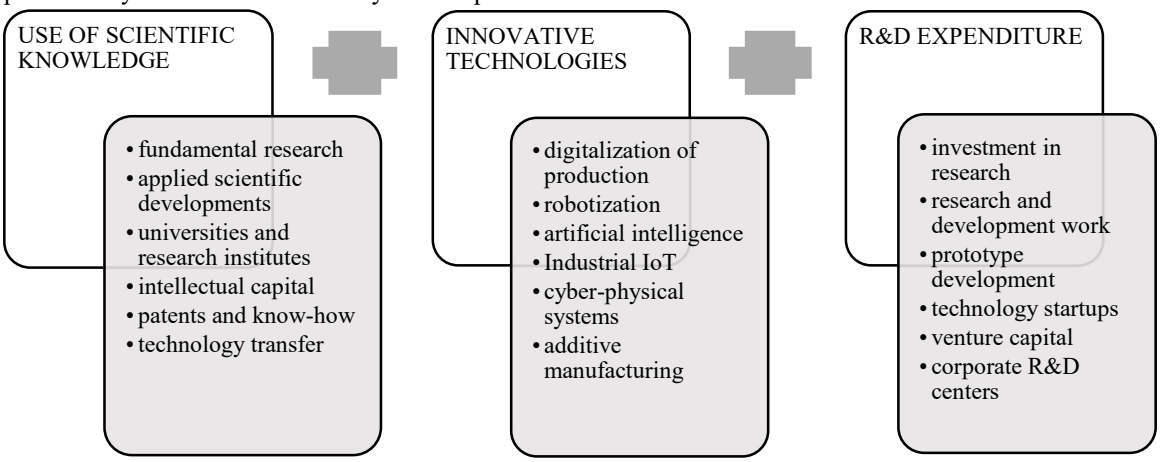

Figure 1: Key elements of the formation of a high-tech production system
Source: compiled by the authors based on their own research

So, the basic blocks of a high-tech production system are:

1. Use of scientific knowledge, which forms the intellectual basis of high-tech production. Scientific knowledge arises as a result of fundamental and applied research and becomes a source of technological innovations. Scientific knowledge ensures the creation of new materials, technological processes, production management algorithms and engineering solutions.

2. Innovative technologies reflect the technological implementation of scientific knowledge in production processes. It is at this stage that scientific developments are transformed into practical technological solutions that increase production efficiency and create products with high added value.

3. The volume of research and development spending reflects the financial and investment basis of high-tech production. It is the high level of investment in research and development that is a key feature of high-tech industries.

Thus, the key elements of the formation of a high-tech production system include the use of scientific knowledge, the application of innovative technologies and the share of research and development costs in the overall cost structure, therefore there is a need to assess the extent to which these elements are implemented at the level of national economies. Since the development of high-tech production depends not only on the availability of technological solutions, but also on institutional, financial and human resources, it is important to use appropriate statistical indicators that reflect the country's innovation potential.

To assess the development opportunities of a high-tech production system, we will use indicators such as gross research and development costs (Gross Expenditure on R&D) as a percentage of GDP, the employment level in knowledge-intensive sectors of the economy, as well as the share of high-tech

production in the total volume of industrial production. A combined analysis of these indicators will allow assessing the level of innovative development of the economy, the efficiency of using human and scientific potential, as well as the country's capabilities to create and produce high-tech products.

GERD (Gross Expenditure on Research and Development) reflect the share of economic resources aimed at creating new knowledge, technologies and innovations. The indicator is defined as the ratio of total spending on research and development to the country's GDP. This indicator is widely used in international statistics as a key indicator of the innovation potential of the economy, since a high level of R&D funding contributes to the formation of new technologies, the development of intellectual capital and the creation of high-tech products (Fig. 2).

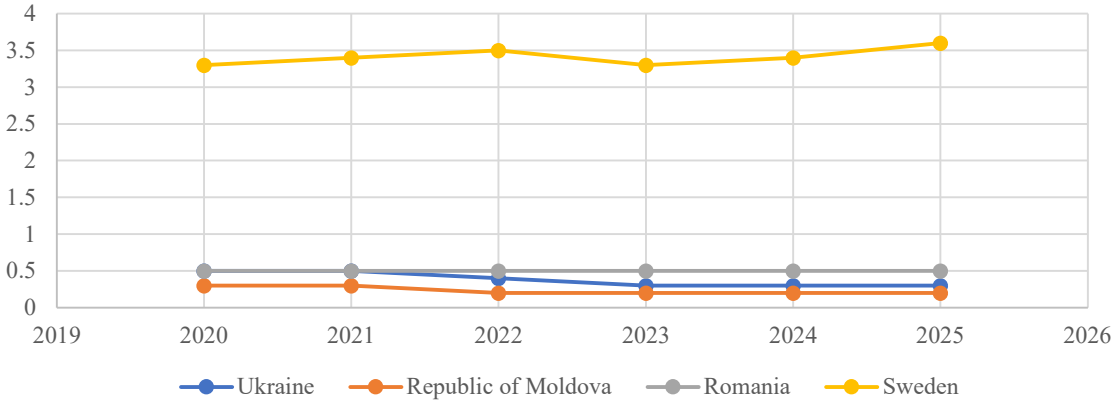

Figure 2: Dynamics gross expenditure on R&D, % GDP

Source: compiled by the authors based on [12; 17]

The analysis of the dynamics of gross R&D expenditures in the studied countries indicates significant differentiation in the level of innovation financing.

Sweden shows the highest indicators among the countries considered. The share of R&D spending ranges from 3.3 to 3.6% of GDP, which corresponds to the level of the leading innovative economies of the world. The increase in the indicator to 3.6% in 2025 indicates stable state and corporate support for scientific research and technological innovation.

Romania is characterized by a significantly lower level of investment in R&D – about 0.5% of GDP, which is almost seven times less than in Sweden. Despite the stability of the indicator during the analyzed period, this level of funding limits the possibilities for the development of research infrastructure and innovation activities.

Ukraine is showing a trend of decreasing investment in science: from 0.5% of GDP in 2020–2021 to 0.3% in 2023–2025. This dynamics is largely due to economic difficulties and military challenges, which leads to a reduction in funding for scientific research.

The Republic of Moldova has the lowest indicators among the countries studied – 0.2–0.3% of GDP, which indicates limited opportunities for financing scientific research and innovation activities.

Overall, the analysis shows that the level of R&D funding is directly related to the technological potential of the economy: countries with a high share of R&D spending form a more developed high-tech production system.

The employment rate in knowledge-intensive sectors reflects the share of workers employed in industries characterized by high intensity of use of knowledge, technology and innovation (Fig. 3).

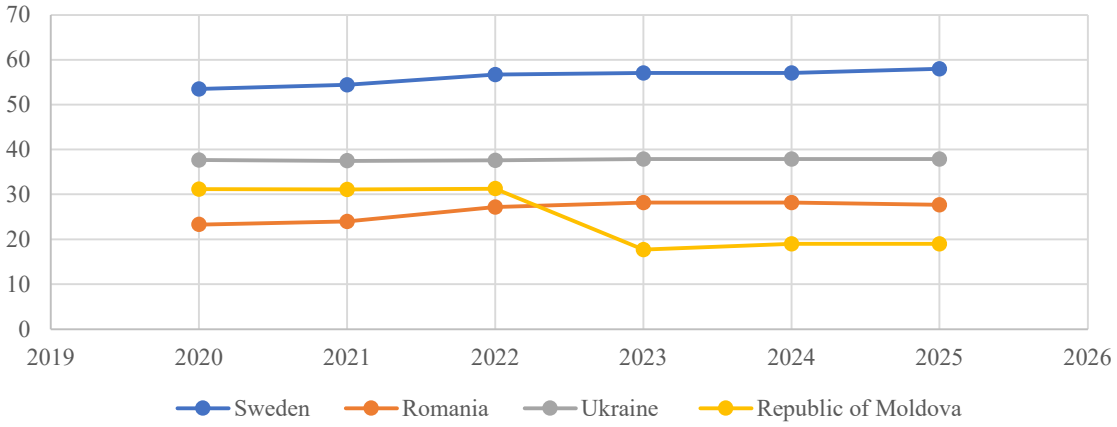

Figure 3: Employment dynamics in the field of knowledge-intensive services (as a percentage of the total labor force aged 15 and over), % GDP
Source: compiled by the authors based on [12; 17]

The share of the country's employed population in knowledge-intensive services is used to assess the structure of the labor market and the level of development of the knowledge economy, since a high level of employment in knowledge-intensive sectors indicates the significant role of human capital in creating added value.

The highest level of employment in knowledge-intensive sectors is observed in Sweden, where this indicator increased from 53.5% in 2020 to 58% in 2025. This trend indicates a high development level of the knowledge economy and a significant concentration of highly skilled labor.

Ukraine has a relatively high rate of around 37–38%, which has remained stable over the period under review. This indicates significant human capital potential, but its implementation is hampered by insufficient funding for innovation activities.

In Romania, the indicator shows positive dynamics - from 23.3% to 27.7%, which indicates a gradual transformation of the economic structure towards the development of knowledge-intensive sectors.

The Republic of Moldova is characterized by unstable dynamics of the indicator. After relative stability in 2020–2022 (about 31%), in 2023 there was a sharp decrease to 17.7%, which is associated with structural changes in the labor market and migration processes.

The share of high-tech production reflects the share of production of high-tech industries in the total volume of industrial production of the country (Fig. 4).

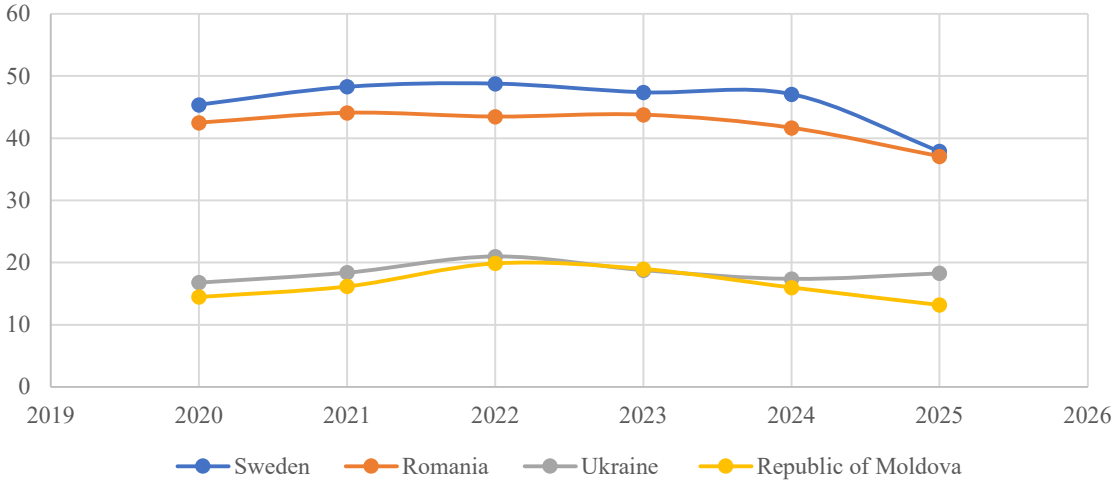

Figure 4: Dynamics of high-tech production (% of total production), % GDP
Source: compiled by the authors based on [12; 17]

Share of high-tech production in total production characterizes the technological structure of the industry and the level of its innovation.

The highest values of the indicator are demonstrated by Sweden, where the share of high-tech production in 2020–2024 was 45–48%, which indicates a high level of technological specialization of the economy. At the same time, in 2025 there is a decrease to 37.9%.

Romania has a relatively high rate of 41–44%, which indicates the significant role of high-tech industries in the country's industrial structure.

In Ukraine, the share of high-tech production is much lower – 16–21%, reflecting the dominance of medium- and low-tech industries in industry.

The Republic of Moldova demonstrates a similar situation - the indicator fluctuates between 13–20%, which indicates limited development of the high-tech sector.

The comprehensive analysis of the three indicators allows us to assess the innovative potential of countries and their capabilities in the production of high-tech products.

The most balanced model of development of a high-tech production system is demonstrated by Sweden, which combines a high level of funding for scientific research, a significant share of employment in knowledge-intensive sectors, and a high level of development of high-tech production. This ensures the formation of an effective innovation ecosystem and a high level of competitiveness of the economy.

Romania has a relatively developed high-tech manufacturing sector, but further development of its high-tech manufacturing system may be constrained by insufficient funding for research and development.

Ukraine is characterized by the presence of significant human potential in knowledge-intensive sectors, however, the low level of investment in R&D limits the possibilities of transforming this potential into high-tech production.

The Republic of Moldova has the lowest values for most indicators, which indicates the need to strengthen innovation policy and stimulate the development of the science and technology sector.

Thus, gross expenditure on research and development characterizes the financial basis of innovation activity; employment in knowledge-intensive sectors reflects the level of development of human capital and the knowledge economy; the share of high-tech production characterizes the effectiveness of innovation activity in industry.

To determine the nature of the relationship between the main elements of the formation of high-tech production systems, it is advisable to apply correlation analysis. This approach allows you to assess the degree of statistical dependence between financial, personnel and production factors of innovative development of the economy. The study analyzed the relationship between gross expenditures on research and development as a percentage of GDP, employment in knowledge-intensive activities and the share of high-tech production in the industrial structure. The results of the correlation analysis based on data for Sweden, Romania, Ukraine and the Republic of Moldova for 2020–2025 are given in Table 1.

Table 1. Results of correlation analysis of the relationship between key indicators of the development of high-tech production systems

Indicators	R&D	Knowledge employment	High-tech manufacturing
R&D	1	0.89	0.68
Knowledge employment	0.89	1	0.47
High-tech manufacturing	0.68	0.47	1

Source: compiled by the authors based on their own calculations

The correlation coefficient between R&D spending and employment in knowledge-intensive sectors is 0.89, indicating a very strong positive relationship between R&D investment and human capital development. This means that countries that invest more in scientific research form a more developed knowledge-intensive employment sector. This relationship is explained by the fact that R&D funding stimulates the development of scientific institutions, technology companies, innovation centers and universities, which creates additional jobs for highly qualified specialists.

The correlation between R&D spending and high-tech production is 0.68, which indicates a fairly strong positive relationship. This confirms that investments in science and innovation are one of the key factors in the development of high-tech production. However, the dependence is not maximum, since the development of the high-tech sector is also influenced by other factors: technological infrastructure, institutional support for innovation, the level of integration into global production chains, the state's industrial policy, etc.

The correlation coefficient between employment in knowledge-intensive sectors and high-tech production is 0.47, which is characterized as a

moderate positive relationship. This means that the presence of a significant number of highly qualified workers in itself does not guarantee a high level of development of high-tech industry. To transform human potential into high-tech production, investments in R&D, a developed innovation ecosystem, and effective mechanisms for the commercialization of technologies are necessary.

The correlation analysis shows that a key factor in the formation of a high-tech production system is research and development financing. It is R&D investments that form the basis for the development of knowledge-intensive employment and stimulate the growth of high-tech production.

However, the results also indicate that the effectiveness of transforming scientific and human resources potential into high-tech products depends on the comprehensive functioning of the country's innovative production system, including the institutional environment, technological infrastructure, and industrial policy.

The next stage of the study is the analysis of indicators that characterize the foreign economic results of the functioning of the country's high-tech production system. Unlike previous indicators that reflect the resource base and internal prerequisites for the formation of the high-tech sector (expenditures on R&D, development of human capital and production structure), foreign trade indicators make it possible to assess the real competitiveness of the national economy in the world markets of high-tech products.

In particular, for this analysis, indicators of the share of imports of high-tech products without reimports in the total volume of foreign trade (high-tech imports less re-imports, % total trade), shares of exports of high-tech goods without re-exports (high-tech exports less re-exports, % total trade), as well as the trade balance in the high-tech products segment.

A number of scientific studies confirm that the share of high-tech exports and imports in the structure of foreign trade is an important indicator of the competitiveness of the economy, the level of innovative development, and the country's integration into global technological value chains.

Zapata et al. [63] prove that the growth of the share of high-tech exports is an important factor in the long-term economic development of countries, and based on the analysis of 35 OECD countries, they proved that the key determinants of high-tech exports are R&D spending, foreign investment, the share of highly skilled labor and the quality of the institutional environment.

Falcon & Şahin [47], using data from 20 high-tech exporting countries, confirmed the hypothesis of export-led growth, according to which an increase in the share of high-tech products in foreign trade contributes to an increase in economic productivity.

Kalyuzhna & Dashkov [28] show that analysis of the structure of high-tech exports allows us to assess the potential of a country's innovative development and its ability to integrate into global technology markets.

Makarenko et al. [37] argue that the dynamics of exports of high-tech products is cyclical and significantly affects the rates of economic growth and the production potential of the country, and the instability of high-tech exports can limit long-term economic growth, especially in countries with an insufficient level of technological diversification.

Sezer [48] proves that the growth of investments in high-tech industries directly stimulates the increase in exports of technological products.

Thus, the results of scientific research indicate that the share of imports and exports of high-tech products, as well as the trade balance in this segment, are important indicators for assessing the effectiveness of the functioning of the country's high-tech production system.

The combined analysis of these indicators allows us to assess the level of integration of the country into global technological value chains, its export potential in the field of high technologies, as well as the dependence of the national economy on imports of high-tech goods.

High-tech indicator imports less re-imports (% of total trade) reflects the share of imports of high-tech products in the structure of the country's foreign trade, while re-imports are excluded from it (Fig. 5). From an economic point of view, this indicator characterizes the level of technological dependence of the country on foreign markets, the provision of domestic production with its own technologies, the degree of integration of the economy into global technological chains. The higher the share of imports of high-tech products, the greater the country's dependence on external sources of technology.

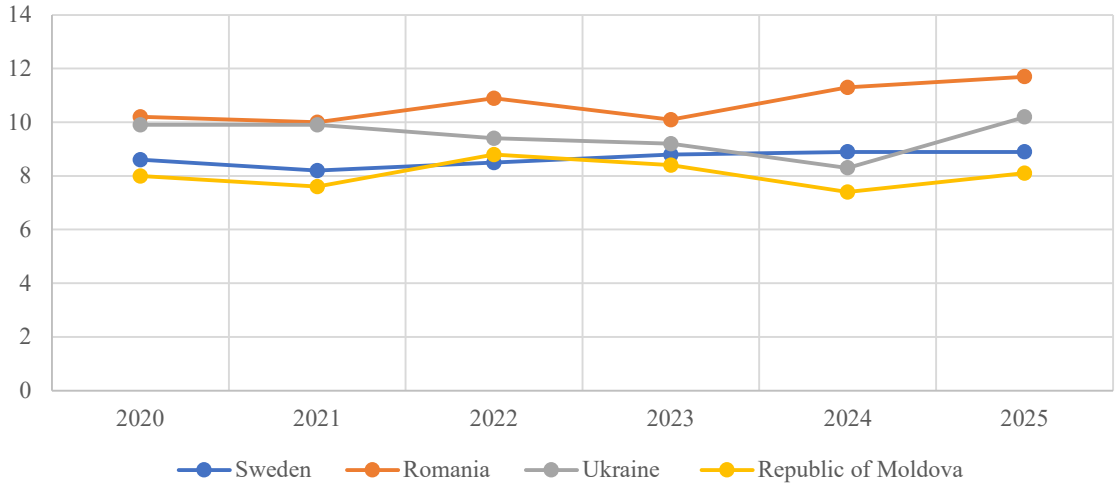

Figure 5: Dynamics high-tech imports less re-imports, % total trade
Source: compiled by the authors based on [12; 17]

Data analysis shows significant differences between the countries studied.

Sweden's share of high-tech imports is relatively stable, fluctuating between 8.2% and 8.9% over 2020–2025. This stability indicates a balanced trade structure, with the country both actively importing technology for production needs and maintaining a significant domestic high-tech sector.

Romania is characterized by a slightly higher level of high-tech imports. Its share increased from 10.2% in 2020 to 11.7% in 2025, which indicates the country's active integration into international production chains and the use of imported technological components in national production.

Ukraine has a relatively high level of imports of high-tech products, ranging from 8.3% to 10.2%. The decline in 2024 to 8.3% is particularly noticeable, due to the economic restrictions of the war period, as well as a change in the structure of imports.

In the Republic of Moldova, the share of imports of high-tech products is the lowest among the studied countries and ranges from 7.4–8.8%, which indicates a limited volume of high-tech trade.

High-tech indicator exports less re-exports (% of total trade) characterizes the share of exports of high-tech products in the country's foreign trade, while re-export operations are excluded from it (Fig. 6). This indicator reflects the development level of high-tech production, the country's competitiveness in international technology markets, and the economy's ability to create products with high added value.

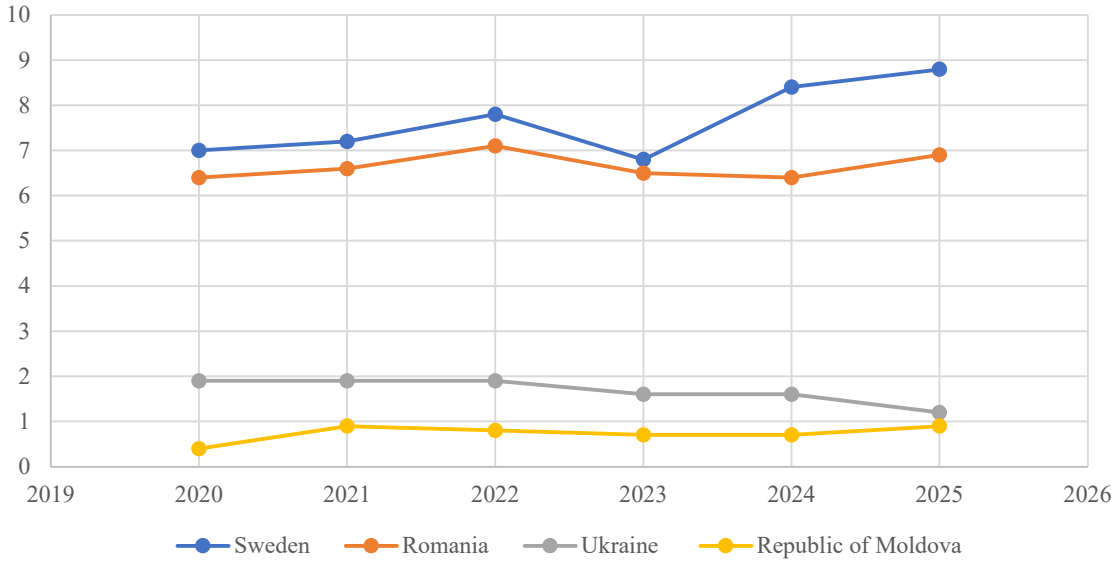

Figure 6: Dynamics high -tech exports less re-exports, % total trade
Source: compiled by the authors based on [12; 17]

The analysis shows significant differences between countries.

Sweden has one of the highest levels of high-tech exports, with the share of such exports increasing from 7% in 2020 to 8.8% in 2025, indicating a strong development of the national technology sector.

In Romania, the figure is slightly lower, ranging from 6.4% to 7.1%. This indicates the presence of high-tech production, but its scale remains smaller than in countries with developed innovation systems.

In Ukraine, the share of high-tech exports is significantly lower – from 1.2% to 1.9%. Moreover, during the period under review, there has been a downward trend in this indicator, which indicates the limited development of high-tech production and the weak representation of Ukrainian products in global technology markets.

The share of exports of high-tech products of the Republic of Moldova is the lowest and amounts to only 0.4–0.9%, which indicates the insignificant development of high-tech sectors of the economy.

The trade balance of high-tech products reflects the difference between imports and exports of technological goods. This indicator allows us to assess whether a country is a net exporter or a net importer of high-tech products (Fig.7). The economic significance of the indicator is that it characterizes the level of technological self-sufficiency of the economy, the competitiveness of national industry, and the country's ability to form a positive trade balance due to high-tech products.

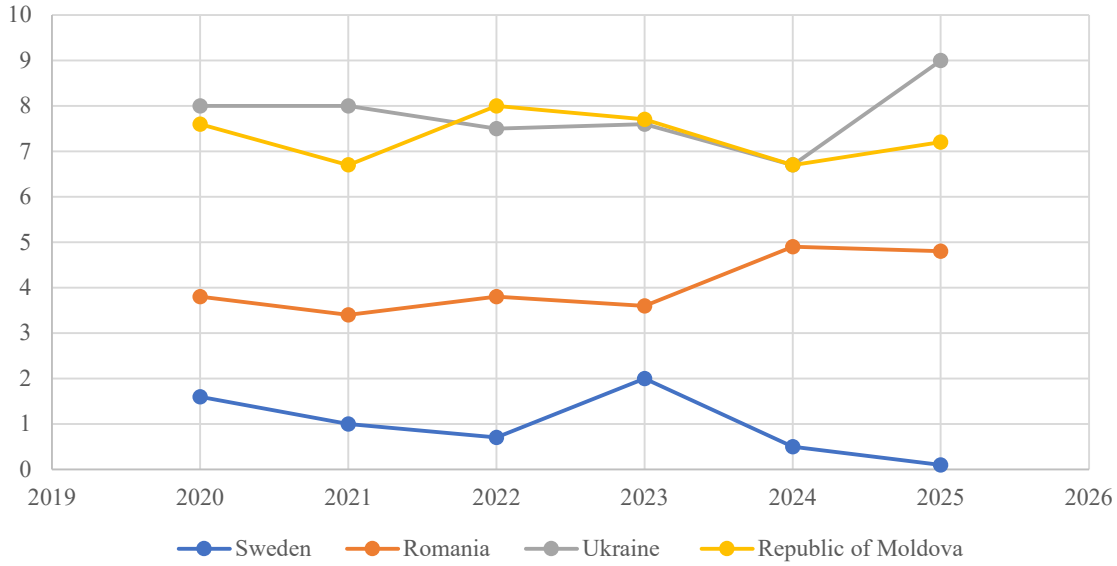

Figure 7: Dynamics trade balance in high-tech products, % total trade
Source: compiled by the authors based on [12; 17]

The results of the analysis demonstrate significant differences between countries.

The difference between Sweden's imports and exports of high-tech products is minimal. The indicator decreased from 1.6 in 2020 to 0.1 in 2025, indicating an almost complete equalization of the trade balance in the high-tech sector.

Romania is characterized by a larger gap between imports and exports of technological products. The indicator ranges from 3.4 to 4.9, indicating a significant dependence on imports of technological goods.

Ukraine has the largest gap between imports and exports of high-tech products – 6.7–9, which confirms the high dependence level of the economy on imports of technological goods and the low level of development of export potential in this sector.

A similar situation is observed in the Republic of Moldova, where the indicator is 6.7–8, indicating significant technological imports with a relatively small volume of high-tech exports.

The comparative analysis of the indicators of imports, exports and trade balance of high-tech products indicates significant differences in the level of development of high-tech production systems of the studied countries. The most balanced high-tech production system is demonstrated by Sweden, where a high development level of the innovative economy ensures an almost equilibrium ratio of imports and exports of technological products. Romania is characterized by moderate development of high-tech production and gradual integration into global technological chains. In contrast, Ukraine and the Republic of Moldova demonstrate significant dependence on imports of high-tech goods, which indicates the limited capabilities of national economies in the production of technologically complex products and the need to intensify innovation and industrial policies.

The results obtained indicate that the formation of an effective high-tech production system depends on the complex interaction of financial, personnel and production factors. However, modern global economic transformations, technological competition, digitalization of production, as well as geopolitical risks significantly change the conditions for the functioning of high-tech sectors of the economy. In such conditions, traditional models of development of innovative production systems need to be reconsidered and adapted to new challenges.

That is why the transformation of strategies for the development of high-tech production systems is of key importance, which involves reviewing approaches to financing innovations, developing human capital, integrating into global technological chains, and forming new models of technological competitiveness. This transformation is aimed at ensuring the stability of national economies, increasing their technological autonomy, and strengthening their positions in global markets for high-tech products (Fig. 8).

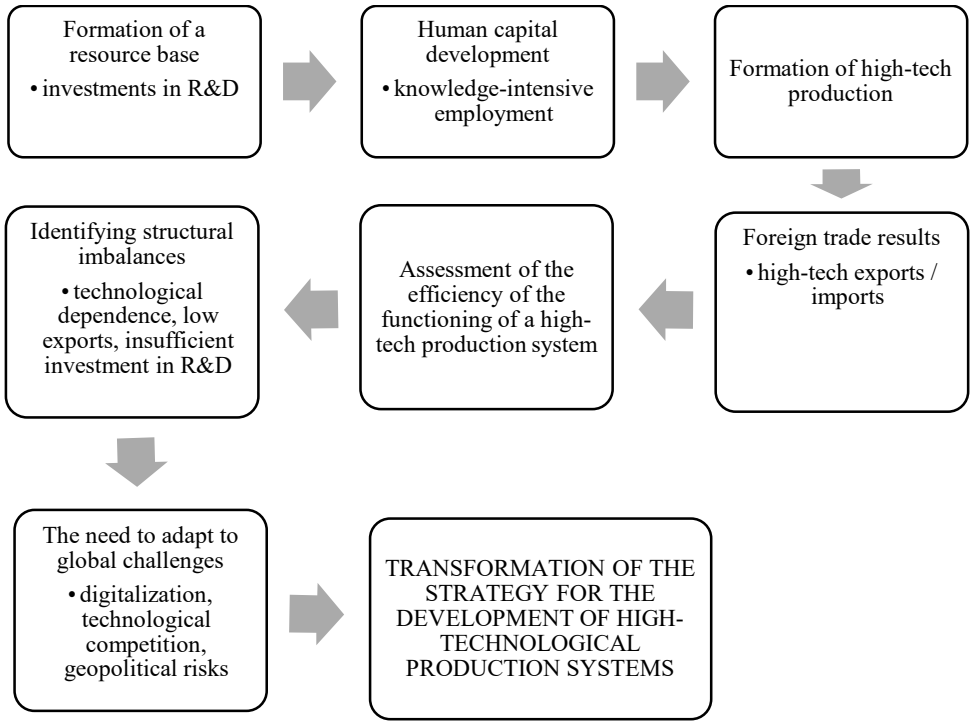

Figure 8: Logical scheme of transition to transformation of the development strategy of high-tech production systems

Source: compiled by the authors based on their own research

The presented scheme in Fig. 8 reflects a consistent mechanism of transition from resource prerequisites for the formation of high-tech production systems to the need to transform their development strategies. At the initial stage, investments in research and development play a decisive role, which form the basis for the development of human capital and the knowledge economy. In the future, this potential is transformed into the development of high-tech production and the formation of export potential in the field of technological products. Assessment of the results of the functioning of high-tech sectors allows us to identify structural imbalances, in particular, an insufficient level of innovative investments, technological dependence on imports and limited opportunities for the export of high-tech products. The presence of this imbalances in combination with modern global challenges necessitates the strategic transformation of high-tech production systems aimed at increasing their innovative capacity, technological autonomy and competitiveness in world markets.

The analysis of key indicators of the development of the high-tech sector (expenditure on research and development, employment in knowledge-intensive activities, the share of high-tech production and indicators of foreign trade in high-tech products) revealed significant differences in the capabilities of countries to form competitive high-tech production systems.

The results obtained indicate that the effectiveness of the functioning of such systems depends not only on the resource potential of innovative development, but also on the ability of the economy to transform scientific knowledge and human capital into technologically complex products and export advantages. At the same time, modern global economic transformations, increased technological competition, digitalization of production and increased geopolitical risks create new challenges for the development of high-tech sectors. In such conditions, there is an objective need to review traditional approaches to the development of the innovative industry and the formation of new strategic guidelines for its functioning. The logic of such a transition to the transformation of strategies for the development of high-tech production systems is presented in Fig. 9. This model demonstrates how external and internal factors change the traditional logic of the development of high-tech sectors and form new strategic guidelines for the state and enterprises.

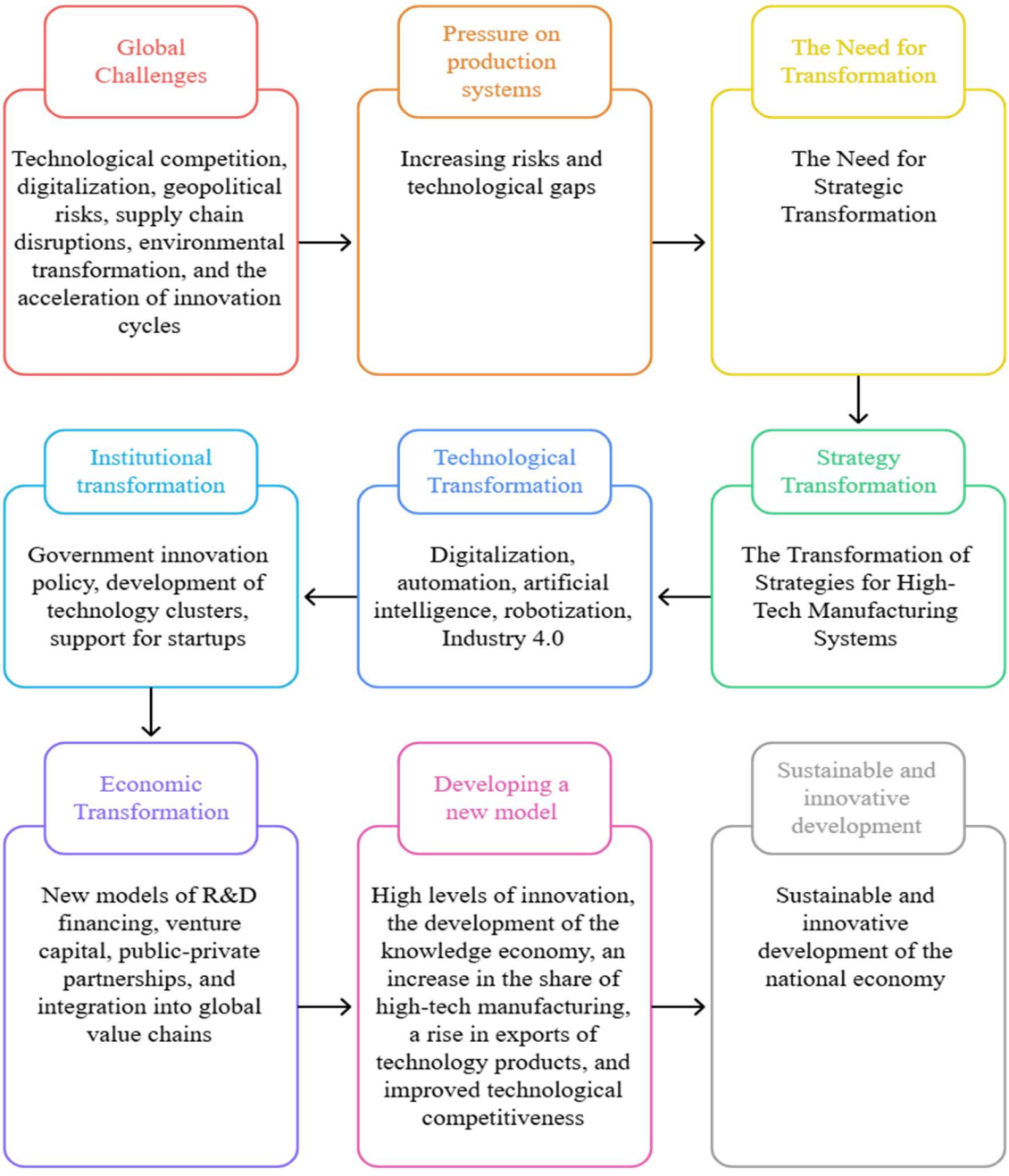

Figure 9: Transformation model of the development strategy of high-tech production systems
Source: compiled by the authors based on their own research

The proposed model demonstrates that the transformation of strategies for the development of high-tech production systems is taking place under the influence of a set of global challenges, among which the digitalization of production, technological competition between countries, disruption of global production chains, and growing geopolitical risks play a special role. These factors create additional pressure on existing production systems and necessitate their strategic adaptation.

In these conditions, the transformation of development strategies occurs simultaneously in several interrelated directions: technological, institutional and economic. Technological transformation involves the introduction of digital technologies, automation and the development of the concept of industry 4.0. Institutional transformation is associated with the improvement of state

innovation policy, the development of scientific clusters and the support of startup ecosystems. Economic transformation is aimed at the formation of new mechanisms for financing innovations and the integration of national economies into global technological value chains.

The result of these changes is the formation of a new model of a high-tech production system, characterized by a high level of innovative activity, an increase in the share of high-tech production, and increased competitiveness in global markets.

5. DISCUSSION

The obtained results of the analysis allow us to deepen our understanding of the structural factors of the formation of high-tech production systems and confirm the complex nature of the technological competitiveness of national economies [14; 33; 36; 40; 52]. The conducted comparative analysis of Sweden, Romania, Ukraine and the Republic of Moldova demonstrates that the development of effective high-tech production systems is determined not by a single factor, but by the interaction of financial, personnel, institutional and technological prerequisites for innovative development.

First of all, the results of the study confirm the key role of investments in research and development (R&D) in shaping the innovative potential of the economy [13; 60]. Countries with a higher share of R&D expenditures demonstrate a more developed structure of high-tech production, a greater concentration of knowledge-intensive employment and a higher level of integration into global technology markets [33; 34]. This pattern is clearly observed in the example of Sweden, where systematic state and corporate support for research ensures a high level of innovative activity, the development of high-tech production and a significant export potential of technological products [18; 33].

At the same time, the analysis shows that human capital alone does not guarantee the formation of a powerful high-tech sector [7; 30]. In particular, in the case of Ukraine, a relatively high level of employment is observed in knowledge-intensive sectors, but the limited level of funding for research and development significantly hinders the transformation of this potential into the production of high-tech products [25; 32]. The structural imbalance indicates the presence of institutional and financial barriers that limit the commercialization of scientific results and the integration of the scientific sector with industrial production [30].

An important result of the study is also the identification of significant differences in the structure of international trade in high-tech products between the studied countries [63; 47]. The analysis shows that countries with developed innovation systems are characterized by a more balanced structure of exports and imports of technological products [6; 63]. In particular, Sweden demonstrates an almost equilibrium balance of high-tech trade, which indicates its high technological self-sufficiency and deep integration into global production chains [18; 27].

In contrast, Ukraine and the Republic of Moldova are characterized by significant dependence on imports of high-tech products with a relatively low level of their exports [27]. This structure of foreign trade indicates the limited capabilities of national economies to produce complex technological products and insufficient integration into international technological value chains [34]. In turn, Romania occupies an intermediate position, demonstrating the gradual growth of high-tech production and more active integration into European production networks [6].

The results also confirm the importance of a systemic approach to the development of high-tech production systems [33; 40]. The formation of a competitive high-tech sector depends not only on the level of funding for scientific research or the availability of human capital, but also on the effectiveness of the institutional environment, the development of innovation infrastructure, access to financial resources and the level of integration of the economy into global technological networks [14; 33].

In the current conditions of global economic transformation, new technological and geopolitical challenges also have a significant impact on the development of high-tech sectors [18; 52; 65]. Accelerated digitalization of production, the development of Industry 4.0 technologies, automation, robotization and the spread of artificial intelligence are significantly changing the structure of modern production systems and forming new requirements for the state's innovation policy.

Thus, the conducted research confirms that the effective development of high-tech production systems requires systemic interaction of scientific potential, human capital, innovation infrastructure and state policy supporting technological development [33; 40].

6. CONCLUSIONS

The analysis allows for a comprehensive assessment of the conditions for the formation and

results of the functioning of high-tech production systems in the countries studied. For this purpose, a set of interrelated indicators was used that reflect different stages of the formation of an innovative economy: resource potential (expenditure on R&D), human capital development (employment in knowledge-intensive sectors), the structure of industrial production (share of high-tech production), as well as the results of integration into global technological markets (export and import of high-tech products). Thus, the results obtained directly correspond to the stated goal of the study regarding a comprehensive analysis of the prerequisites, structure, and results of the functioning of high-tech production systems.

Resource base of innovative development – analysis of gross expenditure on research and development shows significant differentiation between countries. Sweden demonstrates one of the highest indicators in Europe (over 3% of GDP), which indicates systemic state and corporate support for innovative activity. Romania, Ukraine and the Republic of Moldova are characterized by a significantly lower level of investment in R&D (0.2–0.5% of GDP), which significantly limits the development opportunities of the high-tech sector. This confirms the importance of the resource component as a basic element of the formation of an innovative economy, as defined in the research objective.

Human capital and the knowledge economy – the share of employment in knowledge-intensive sectors confirms the significant role of human capital in the formation of high-tech production systems. In Sweden, more than half of the employed population works in knowledge-intensive activities, which creates a favorable environment for the generation and commercialization of innovations. In Romania and Moldova, this indicator is significantly lower, while Ukraine demonstrates a relatively high level of knowledge-intensive employment, but the potential of human capital is not fully transformed into high-tech production. The results obtained allow us to deepen our understanding of the role of human capital as a key factor in the structural transformation of the economy, which corresponds to one of the areas of research.

The structure of industrial production – the share of high-tech production in Sweden and Romania is significantly higher than in Ukraine and Moldova. This indicates a more developed innovation infrastructure, deeper integration into global production chains, and a greater orientation of the economy towards the production of products with high added value.

The analysis of the indicators of imports and exports of high-tech products confirms the identified structural features. Sweden is characterized by a balanced structure of high-tech trade and a significant share of exports of technological products. Romania is actively integrating into international production networks, which leads to simultaneously high indicators of imports and exports of technological goods. In contrast, Ukraine and the Republic of Moldova demonstrate significant dependence on imports of high-tech products with a relatively low level of their exports.

A comprehensive analysis allows us to trace the logical chain of formation of a high-tech economy: investments in science → formation of human capital → development of high-tech production → growth of exports of technological products. The establishment of such a relationship confirms the research hypothesis and demonstrates the systemic nature of the formation of high-tech production systems.

Thus, the countries that provide systematic support for scientific research and innovation gain competitive advantages in the production and export of high-tech products.

At the same time, the conducted research allows us to conclude that even with a certain scientific potential and human capital, the effectiveness of the functioning of high-tech production systems largely depends on the ability of the national economy to adapt to modern global transformations. Among such transformations, the accelerated digitalization of production, the development of Industry 4.0 technologies, increased competition in global high-tech markets, disruption of global supply chains, as well as increased geopolitical risks play a key role. Taken together, these factors significantly change the conditions for the functioning of high-tech sectors and form new requirements for the strategic management of their development.

In this context, the results of the analysis indicate the need to rethink existing approaches to the development of high-tech production systems and transition to new strategic models of their functioning.

Taking into account the obtained results, the study proposes a conceptual model of transformation of the strategy for the development of high-tech production systems, which reflects the relationship between the resource prerequisites for innovative development, the institutional conditions for the functioning of the innovative economy and the strategic mechanisms for increasing technological competitiveness. The proposed model demonstrates that the transformation of strategies for the

development of high-tech production systems should occur simultaneously in several interrelated directions: technological, institutional and economic, which ensures the formation of a new model of innovation-oriented economic development.

Therefore, the strategic transformation of high-tech production systems is a necessary condition for ensuring sustainable innovative development, increasing the efficiency of the use of scientific and technological potential, as well as strengthening the positions of countries in the global system of production and trade in high-tech products.

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Writing – review & editing: Svitlana Filyppova, Volodymyr Filippov.

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