The Analysis of Trends and the Assessment of the Worldwide High-Tech Production Development

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Abstract. The purpose of the article is to analyze the trends and assess the level of the development of high-tech production in various countries worldwide, as well as to theorize the directions of scientific and technical development of the country by means of increasing the value of innovative products. The prerequisites for the timeliness of mainstreaming of the development of high-tech production for national economies, including GDP growth and improving the competitiveness of the country in global markets have been analyzed. The main aspects of the fourth technological revolution have been identified. The need for regular monitoring of the indicators reflecting the state and the level of the development of high-tech industries in the countries worldwide has been demonstrated. A correlation and regression model of the dependence of the share of high-tech industries in the GDP structure has been developed for the positioning of individual countries in the global technological space with regard to the key market leaders. The model makes it possible to predict the changes in the contribution of high-tech industries to the GDP of the country by means of varying the indicators of scientific and technical activity. A model of the value creation chain for technology-intensive products with account of the institutional means of ensuring scientific and technical development as well as its strategic management at various levels of management (international, national, and local) has been proposed.

1. Introduction

The social and economic upheavals observed in the global economic system over the past decades, as well as the expected structural and technological changes, are already manifesting themselves in the global community. In the estimation of experts from developed countries [1-8], the ongoing transformations will soon result in dramatic changes in the processes of value creation. In this regard, forecasting technological development and determining the place of individual countries in the market of high-tech and advanced technology products and services is deemed necessary, despite the high volatility and the uncertain overall structure of the global market.

The significant technological changes caused by the breakthrough of the scientific research due to the Fourth industrial revolution are already evident through their destructive nature for many traditional sectors of the economy. The above raises the importance of research into the expected dramatic upheavals resulting from technological development and the need to assess the implications for creating customer value at the early stages of the change processes.

The expected changes in setting up and developing modern business necessitate the emergence of new approaches and the development of new technologies. The changes in technologies and products arising from new discoveries in science can only be realized in the market subject to the availability of an appropriate infrastructure, a favorable environment and new business models aimed at creating consumer value.

2. Relevance

In the current conditions, ensuring sustainable economic growth of the country and improving the competitiveness of the national economy in global markets requires the development of the high-tech sector of the economy and an increase in the share of high-tech industries in the GDP structure. The timeliness of the development of high-tech industries is caused by the need to solve the global problems of humankind and ensure an increase in labor efficiency, as well as by the emergence of fundamentally new products and services. The modern states claiming leading positions in the international rankings of innovative and technological development are interested to achieve high indicators of the development of high-tech production and the creation of new technologies.

The theoretical and applied aspects of the development of high-tech production and advanced technology products have been studied by many foreign and domestic scientists. The above issue has been considered in the works of Avdeev A. [1], Bendikov M. [2] , Braguinsky S. [3], Voychak N. [4], Glazyev S. [5], Danko T. [6], Drexler E. [7], Kelley T. [8], Kizim N. [9], Roco M. [10], Matyushenko I. [11], Perez C. [12], Ray O. [13], Rigby D.[14], Smil V. [15], etc.

It is the manifestation of the trends of the Fourth technological revolution that determines the mainstreaming of the development and the increase in the share of high-tech products and industries in the economies of individual countries of the global market. Thus, the world-famous American scientist E. Drexler [7] notes that nanotechnologies are the basis for the formation of the future civilization of the XXI century in the transition to the so-called atomically precise production (APP). Nanotechnologies allow for a dramatic improvement of energy efficiency, a reduction of materials consumption in the modern technosphere, and a decision of the diminishing resources issue. At the same time, experts of the Massachusetts Institute of Technology (MIT) identified the new industrial revolution as a biomedical revolution [17]. According to MIT researchers, the prospects for the development of high-tech industries will be closely related to the convergent life science, physical sciences, and engineering. The biomedical revolution includes three stages: the 1st stage is the development of molecular and cellular technologies, the 2nd one is the development of genomics, and the 3rd one is the convergence of technologies.

In 2011, at the initiative of German business leaders, politicians, and scientists, headed by Charles Gridstuffer (PLN Siemens Software) there appears another concept of the Fourth industrial revolution, called “Industry 4.0”, which is referred to as a means of improving the competitiveness of German manufacturing industry through the integration of “cyber-physical systems” (or CPS) and production processes [16]. CPS is an integration of machines and human labor, using the Internet through the process of creating a network of machines that not only produce high-precision products, but also autonomously modify production patterns as needed.

This concept defines the following priority areas for the development of high-tech production: the development of control systems of production processes (introduction of sensors of equipment status, parameters of raw material flows and state (size, composition, etc.) of manufactured products); the emergence of intelligent production control systems (optimization of all internal and external business processes), robotics and intelligent systems in the field of “Internet of things”; the emergence of systems of creation and transformation (cultivation) of material objects, including 3D printing; the development of infusion technologies; promising methods of surface treatment and work with thermoplastics (including growth technologies); the introduction of multidimensional modeling of complex products, which makes it possible to optimize their various parameters (strength, life, production processes) and customization of the object, a modification of products based on the individual needs of the customer; the emergence of new materials, effective in the creation of

advanced actuation devices for the growth of technology: composite materials, nanomaterials, and others [18-23].

According to experts implementing this concept, the creation of new markets and industries, contributing to productivity growth, competitiveness of individual sectors, and national economies, promotes the emergence of technologies of "Industry 4.0" in combination with Smart TEMP factors where T (technology) stands for smart technologies, E (environment) is a sensible environment, M (manufacturing) stands for smart production, and P (products) is smart products [11].

The results of the Fourth industrial revolution as evidenced in the national economies of the countries worldwide can be analyzed by assessing the share of high-tech products and services in a country's GDP.

3. Statement of the problem

The development of new technologies and high-tech production involves a certain resource spend, the intensity and efficiency of which employment largely determines the place of individual states in the global research and innovation activity and, thereby, the GDP growth rate, as well as the living standards of the population in general.

The above necessitates a study of the trends of the scientific and innovative development worldwide, as well as a regular monitoring of the indicators reflecting the state and level of the development of high-tech industries in the countries, which are the global market leaders.

The purpose of this paper is to analyze the trends and assess the level of the development of high-tech production in various countries worldwide, as well as to theorise the directions of scientific and technical development of a country by means of increasing the value of innovative products.

4. Theoretical value

A fundamental prerequisite for the positioning of national economies in the global market of high-tech and advanced technology products is the identification of individual indicators characterizing a country's development and production potential. However, the level of the scientific and technological development of a national economy is quite difficult to characterize using single indicators, since it is impossible to reflect the full range of scientific achievements, development, and emergence of new technologies that are employed in communications, medicine, production, and other areas. In addition, many aspects of the creation and dissemination of scientific developments, innovative technologies, and the production of high-tech products such as human capabilities and potential are difficult to quantify within a single national economy. However, even if these indicators could be quantified, the lack of reliable data makes their comprehensive analysis impossible. Therefore, there arises a problem of choosing such indicators, as well as interpreting them quantitatively.

5. Practical value

In this regard, in order to identify the main factors that influence the development of high-tech production in a country, a hypothesis about the impact of the factors was formed on the basis of the analysis of literary sources and the existing techniques that allow both assessing the level of scientific and technological development of a country and determining its potential for development.

Based on the study of the methodology of the integrated assessment of the scientific and technical potential of a country (Japan), the calculation of the Technology Achievement Index (TAI), the Global Innovation Index (GII) [24], (INSEAD), the Good Country Index (USA), the Knowledge Index (World Bank) and the Summary Innovation Index (the Netherlands), as well as the integrated assessment of the scientific and technical potential of a country (the USA), the structural analysis of the innovation activity of an area (S. V. Cortov), and the factor analysis of the innovation potential of a territory (E. P. Amosenko,) and other means several key indicators have been identified.

The assessment of the development of high-tech production in several countries of the world has been made on the basis of the identified indicators. The results are presented in Figure 1[25].

Based on the data in Table 1, it can be concluded that high-tech products have the largest share in GDPs of the US (77%) and Japan (72%). The share of high-tech products and services in GDP of Russia is 42%. In the context of the Fourth technological revolution, the scientific and innovative activity should account for 65-75% of GDP, which corresponds to the level of the developed countries.

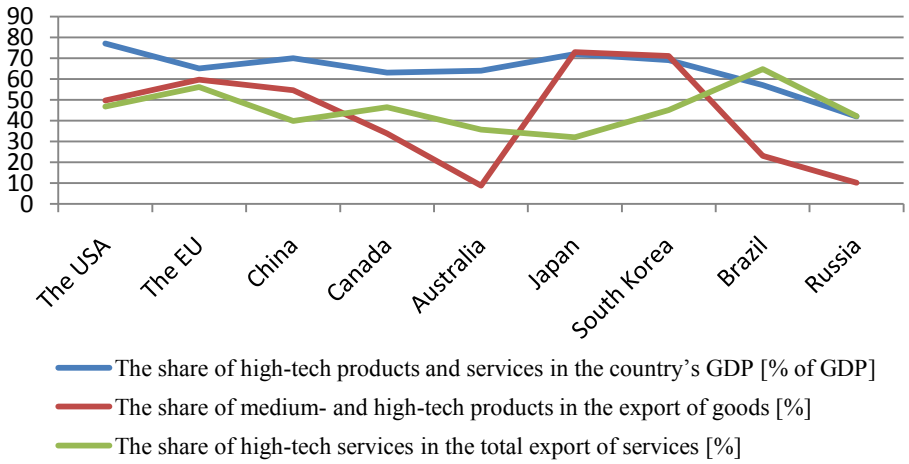

Figure 1. The indicators of scientific and technical activity of the world's leading countries in 2016.

To position individual countries in the global technological space with regard to the key market leaders, a correlation and regression model of the dependence of the share of high-tech industries in the GDP structure and the indicators presented in Table 1 has been developed. To confirm the influence of the identified indicators on the change in the share of high-tech industries, the correlation coefficient has been calculated [27]. The calculation results are presented in Table 1.

Table 1. Correlation coefficients of the impact of the indicators of the scientific and technical activity and the share of high-tech products in a country's GDP (based on the 2010-2016 data).

The name of the indicator	Value
Public spending on R&D [% of GDP]	0,437643
Private spending on R&D [% of GDP]	0,649337
Applications for patents [per 1 billion euros of GDP]	0,587156
The number of new doctorates per mille of the population aged 25-34, [ea]	0,009058
The share of the population aged 25-64 with higher education [%]	-0,1588
The number of coauthored international scientific publications per 1 million of the population [ea]	0,139406
The share of national scientific publications among the 10% most cited worldwide [%]	0,602165
Joint public-private publications per 1 million of the population [%]	0,710652
The share of medium- and high-tech products in the export of goods [%]	0,709955
The share of high-tech services in the total export of services [%]	-0,21733
The share of foreign revenues from the sale of licenses and patents in GDP [%]	0,629169

Based on the results of the calculations and the assessment of the correlation strength, the model will include only the indicators with a strong (±0,7 to ±1) and average (±0,3 to ±0,699) correlation, that is, the number of new doctorates per mille of the population aged 25-34, the share of the population aged 25-64 with higher education, the number of coauthored international scientific

publications per 1 million of the population, and the share of high-tech services in the total export of services will be excluded from the model.

Based on the 2010-2016 data for the previously selected countries, a linear regression model of the impact of the indicators of scientific and technical activity and the share of high-tech products in a country's GDP has been developed. The model is presented by Formula 1:

Y=73.62*X1-55,55*X2-26,34*X3+9,64*X4+3,2*X5+0,71*X6+0,42*X7-69,83(1)

where Y is the share of high-tech products and services in a country's GDP [% of GDP]; X1 is public spending on R&D [% of GDP]; X2 is private spending on R&D [% of GDP]; X3 is applications for patents [per 1 billion euros of GDP]; X4 is the share of national scientific publications among the 10% most cited worldwide [%]; X5 is joint public-private publications 1 million of the population [%]; X6 is the share of - medium- and high-tech products in the export of goods [%]; X7 is the -share of foreign revenues from the sale of licenses and patents in GDP [%].

Thus, on the basis of the proposed model, it is possible to predict the change in the contribution of high-tech industries to a country's GDP by changing the values of the indicators of scientific and technical activity. The improvement of a country's competitiveness and its position in the global technological space are determined by the specific measures taken by the government of a certain country as regards the encouragement of the development of science and the application of its results to production with a focus on the creation of consumer value [29]. In order to improve the process of creating value for consumers during the production of high-tech products, a model with identified stages of the high-tech product value creation, as well as institutional means of ensuring scientific and technical development and its strategic management at various levels of management (international, national and local) has been proposed (Fig. 1).

6. Conclusions

The development of high-tech industries in the context of the Fourth industrial revolution is called forth by the need to improve the competitiveness of domestic producers in foreign and domestic markets under the conditions of penetrating integration of the country in the global markets. The above necessitates further research and the commercialization of its results by means of developing high-tech industries and improving the innovative activity of business structures. To commercialize the results of research and create value for consumers, it is necessary to form a developed infrastructure that will support scientific and technological development, provide the necessary flow of funds for research and development, both from the state and private investors, ensure an increase in marketable inventions and develop public-private partnership.

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