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Nadiia Stezhko ✉; Ahmed J. Obaid; Mykola Palinchak; ... et. al

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Assessment of Ukraine′s Potential in Transition to Industry 4.0 and Directions of its Development in the Context of Globalization

Nadiia Stezhko[1,a)], Ahmed J. Obaid[2,b)], Mykola Palinchak [3], Ihor Korol [4], Myroslava Tsalan[1], Kateryna Brenzovych[1], Olena Zayats[1]

[1]*University of the State Fiscal Service of Ukraine, Irpin, Ukraine*
[2]*Faculty of Computer Science and Mathematics, University of Kufa, Iraq*
[3] *State Higher Educational Institution "Uzhhorod National University", Uzhhorod, Ukraine*
[4] *John Paul II Catholic University of Lublin, Lublin, Poland*

Corresponding author: [a)] nadijastezhko@gmail.com
[b)] ahmedj.aljanaby@uokufa.edu.iq

Abstract. The article assesses the state of readiness of the Ukrainian industry to the challenges of Industry 4.0, which showed that, despite the difficult conditions in which the domestic industry found itself, namely: the decline in the volume of industrial production in the processing industry, the difficult economic conditions caused by the systemic problems of the industry, the considerable deterioration of the capital stock, the insufficiency of financial means for its renewal and dependence on imported raw materials, in Ukraine there are successful cases for development and implementation of 4.0 industry technologies.
Assessment indicators of readiness of Ukrainian industry for development in direction of Industry 4.0 are reasoned. These indicators allow to analyze processes of creation, transfer, use of knowledge, increase of intellectual capital, application of the latest technologies and know-how in the production, the originality and complexity of the products on the market and the share of value added in them. Recommendations for the development of enterprises in the conditions of Industry 4.0 are given. It is noted that such development does not require the abandonment of traditional production III-IV technological systems, but in the context of global economic orientations and Industry 4.0 takes on specific features, namely it allows industrial enterprises to change themselves rapidly and qualitatively in a short period of time.
The experience of developed countries in stimulating industry 4.0 has been summarized and it has been proved that competitiveness and economic growth depend entirely on stimulating industry 4.0 and achieving technological leadership.

INTRODUCTION

The current period of the global economic development has obvious signs of global turbulence, which can radically change the world. The restructuring of the world economy stems from changes in technological patterns. The process of technological change occurs approximately once-in-a-half-century and is accompanied by technological revolutions. These technological revolutions lead to the emergence and collapse of financial bubbles, devalue a significant part of production and human capital, causing economic crisis and depression. Nowadays, the end of the next economic cycle coincided with the outbreak of the pandemic of the previously unknown virus (COVID-19) and the record collapse of oil prices. This crisis has already become the worst in recent decades: according to the IMF estimates, the expected

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fall in GDP in 2020 can be 5, 9 % in the USA, 7,5 % - in the Eurozone, 7,7 % - in Ukraine [1]. All these reasons inevitably provoke the emergence of new challenges, risks and threats related to changes in the structure of the world economy and, consequently, to fundamentally new competitive processes taking place in the context of changes in technology, communications etc.

At the same time, for countries, which are able to master and scale cyber-physical productions of a new technological system in time, opportunities open up to «make a leap» in economic development, before others by mastering a new «long wave» development and launching a new cycle of capital accumulation. It should be noted that world history already knows similar examples. In the past, State incentives occured mainly through the arms race and a corresponding increase in State spending on research and development (R&D). That is how chemical and nuclear technology, ICT and the electronic industry have developed in the last century.

In the near future, health care, as well as the medical and pharmaceutical industries, as leading industries of the new technological order, have been updated by the COVID-19 pandemic, may receive an additional boost for growth. The almost complete world-wide imposition of quarantine measures and restrictions on the movement of citizens, on the one hand, reduces the cost of information technology for those consumers who have been quarantined, and, on the other hand, provide the impetus for further ICT development through increased demand for e-commerce services, distance education, home appliances and remote workplaces. States have invested enormous resources in the provision of public spaces and transportation by means of video-recording, surveillance, facial recognition, movement and health control. On this basis, artificial intelligence systems are developed that operate on large amounts of data («big data») and require high-speed Internet, super-computer and high-performance software for processing. This in turn stimulates the development of nanotechnologies for the production of computing equipment with appropriate performance, compactness and energy efficiency indicators, as well as other avant-garde technologies of modern «smart» an industry that is now rapidly advancing in the world.

In the developed countries of the world, we are already building not a post-industrial, but an intellectual society (as we call it in Japan, the Super Smart Society, or Society 5.0) with closely integrated cybernetic and physical spaces, in which innovations in science and technology plays a leading role in achieving balanced economic development and solving social problems, and in which cooperation between industry, academia and government is a prerequisite [2].

In the near future, with the digitization and automation of labor markets, there could be a revolution comparable to the historic shift from agricultural production to industrial production: up to 2,030,000 from 75 to 375 million workers (3 to 14 per cent of the global workforce) will be forced to change professions [3].

The most likely outcome of automation (if governments fail to take effective compensatory measures) will be increased inequality in wealth, income and power, as the economic dividends of automation, technology owners, business owners and highly skilled workers are likely to enter.

As a whole, it means that the study of the new industrial revolution should be given the highest priority, because those countries that cannot meet its challenges risk being left on the sidelines of world progress and, not gaining a competitive advantage, only get new problems.

For Ukraine, the special importance of Industry 4.0 is also determined by the fact that its traditional industry is in crisis state and the new «smart» industry has not received due attention from the state. All of the above updates the task of capacity assessment and the scientific support of recommendations for the selection of directions of development of the smart industry.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Industry 4.0 is the subject of a large number of scientific publications, analyses, reviews and reports by international institutions and organizations, but the number of domestic works in this field is not as large. Selected Industry 4.0 issues are addressed in the papers V. Vyshnevskoho, O. Viietskoi, O. Harkushenko, O. Liakha, V. Chekinoi, D. Cherevatskoho [4], S. Kniazieva [5], I. Yehorova, Yu. Ryzhovoi [6], V. Skitsko [7], Stezhko N. [8, 9], V. Khaustovoi [10] and others. The urgency of the transition of the Ukrainian economy to neo-industrial development models with a view to achieving a higher level of social and economic efficiency is highlighted in these papers. Researchers analyze the current state of Ukrainian industry and define the key directions of the new strategy for its development, the transformational potential of the digital economy of Ukraine, taking into account the specificities of domestic producers , proposed directions of attracting investments in the development of industry on the basis of industry 4.0. Unlike many countries in the world, Ukraine still lacks a holistic concept of transition to industry 4.0, so various aspects of this important problem require further special research.

THE RESEARCH OBJECTIVE

The purpose of the article is to assess the potential of Ukraine in the process of transition to Industry 4.0 and to define the prospects of development of this process in the context of globalization.

Presentation of the main material.

According to research by Homeland Security Research Corporation in the report «Industry 4.0 Market & Technologies - 2018-2023», the market volume of the industry 4.0 until 2030 will reach US$1 trillion. Leaders of this market are global technology giants such as: Alphabet-Google, HP, Samsung, IBM, NEC, Microsoft, etc.

In 2018, the industry's global technology market was around US$ 38,000,000, and by 2023 analysts predicted that the market would already be US$ 214 [11]. The US ranks first in this sector (fig. 1).

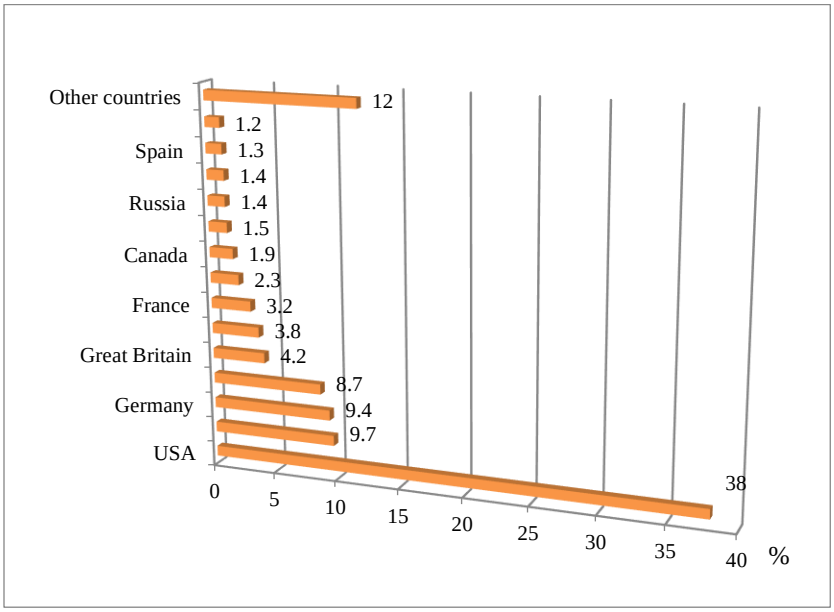

FIGURE 1. Share of industry 4.0 technologies in the world's leading economies in 2018 [12]

In order to analyze the readiness of Ukrainian industry to develop towards Industry 4.0 we will use the following indicators:

Indicators provided by the World Economic Forum to assess the readiness of national industries for the future, in particular the adoption of the technologies of the Fourth Industrial Revolution;

Indicators have been calculated by the Harvard Growth Laboratory, which make it possible to assess the complexity of the economy, in particular the Index of Economic Complexity and data from the State Statistics Service of Ukraine on the structure of industrial production;

World Bank data on industrial value added;

World Bank data on science, technology, innovation and technology development;

The Global Innovation Index and the indicators that measure it are based on the methodology of the International Business School INSEAD, France.

Based on World Economic Forum data presented in the Assessment of Industry's Preparedness for the Challenges of the Future, 2018 (Readiness for the Future of Production Report) [13] we will find out how successful the country is in solving internal problems of preparation for technological challenges of Industry 4.0.

The World Economic Forum's assessment of the readiness of national industries for the future, in particular the adoption of the technologies of the fourth industrial revolution, is based on the identification of two key components: the country's production structure and the main drivers of production, which demonstrate the country's ability to transform production systems.

According to this methodology, countries are divided into four groups, depending on the development of production structure and drivers. Ukraine is in the largest group of developing countries (Nascent), and out of 100 countries the production readiness rating ranks 43rd in 2018. This group of countries includes those that have a limited manufacturing base and do not have strong drivers for industry 4.0 (Table 1).

TABLE 1. Preparedness factors for Ukraine's future, in particular the introduction of technologies of the fourth industrial revolution [14]

Indicator	Rating from 100 countries	Assessment (max. 10)
1. Production structure, total	43	5,17
Including:	41	6,0
production complexity		
scale of production	57	3,9
2. Drivers of production, total	67	4,47
Including:	74	3,5
technology and innovation		
human capital	34	5,8
global trade and investment	59	5,1
institutional framework	94	3,4
stable resources	88	4,6
external demand	58	4,6

The data provided show that Ukraine lags behind the reference countries in terms of both the ranking and the components of the integral index. A more detailed analysis reveals the reasons for the lag, especially in the area of technological development and innovation. According to the production structure, Ukraine is in the first half (43 places) and behind industrial development drivers only 67 places (fig. 2, fig. 3).

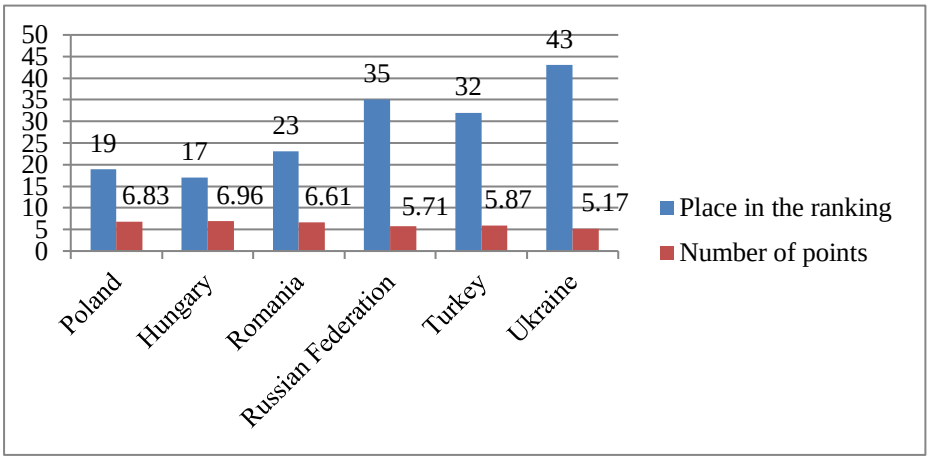

FIGURE 2. Positions of individual countries in the «Assessment of Industry's Preparedness for Future Challenges» (Production Structure Assessment) [13]

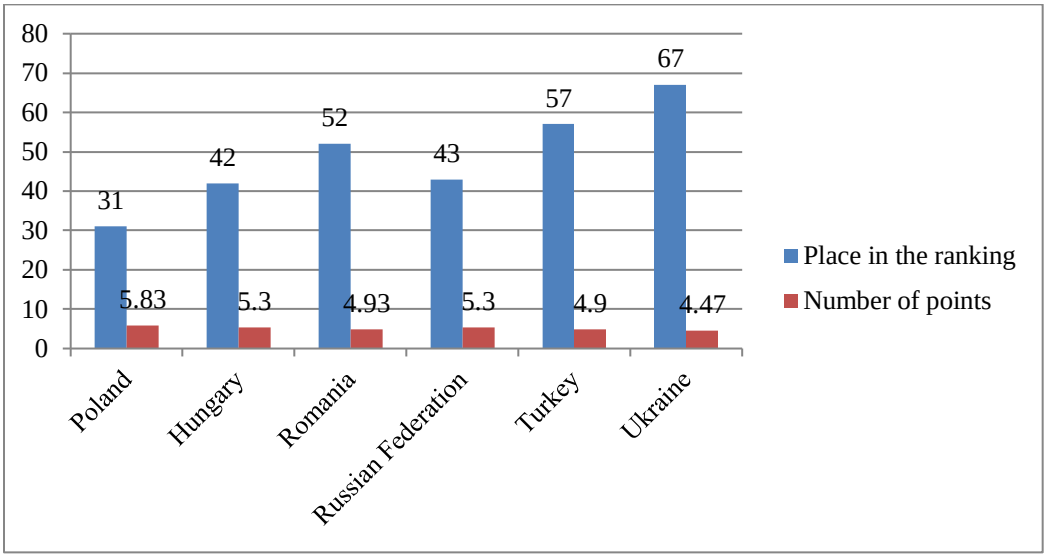

FIGURE 3. Positions of individual countries in the «Assessment of Industry Preparedness for Future Challenges» (Assessment by Production Drivers) [13]

Based on the growth of the Economic Complexity Index (ECI), which was calculated by researchers of the Harvard laboratory, we will characterize the level of possibilities and know-how of the country that are determined by the complexity of its exports. Ukraine is ranked 42nd out of 133 countries. With regard to the lack of export diversification, Ukraine's economy had become less complex than in the previous decade. This indicator assesses the complexity of the goods produced and exported, so it determines how much production requires leading know-how.

Since the complexity of an economy depends primarily on the knowledge embodied in the economy, taking into account the goods and knowledge it exports, including the general level of technology, complex know-how, highly qualified personnel, etc., the Ukrainian economy as compared to other countries of the world (USA, Germany, Great Britain, Poland) does not show significant figures of gross exports and gross imports. This reflects the country's lack of purchasing power and the decline in productive capacity. For example, in 2018, Ukraine reduced ICT exports to 3.99 per cent (11.26 per cent in 2017), amounting to only US$ 2,540,000,000 compared to US$ 69,000,000. in 2017 (Table. 2).

TABLE 2. Commodity groups that occupy the largest share in exports of Ukraine [15]

Commodity group	Gross exports, billion dollars USA		Specific Weight,%		Revealed Comparative Advantage / RCA		Product Complexity Index/PCI	
	2014	2018	2014	2018	2014	2018	2014	2018
Transport services	6,23	5,92	8,77	9,29	-	-	-0,256	-0,494
Sunflower oil	3,27	3,87	4,60	6,07	100	138	-1,07	-0,967
Semi-finished products from iron or non-alloy steel	4,51	3,41	6,35	5,34	50	42,2	-0,595	-0,717
Corn	3,24	3,31	4,55	5,19	30	36,1	-1,07	-1,05
Wheat and meslin	2,55	2,84	3,59	4,45	15,5	24,9	-0,352	-0,547
Iron ores and concentrates	3,46	2,79	4,87	4,38	9,08	11,1	-1,91	-1,86
ICT	6,81	2,54	9,58	3,99	-	-	0,112	0,0396
Rolled flat of iron and non-alloy steel 600 mm or more	2,50	2,08	3,51	3,26	15,7	14,9	0,394	0,48

Insulated wires, cables and other electrical conductors	1,17	1,52	1,65	2,38	3,16	4,3	-0,296	-0,537
Cast iron	0,803	1,11	1,13	1,74	49,1	74,7	-0,867	-0,588
Ferroalloys	1,22	1,09	1,72	1,71	13,8	12,8	-1,06	-0,767

Comparative analysis of the structure of distribution of exports of Ukraine by product groups for 2014-2018 makes it possible to determine the main factors and the extent of their influence on the change in the share of individual product groups. It is a question of change of volumes of export on each commodity group and the general volume of gross export. The impact determination is based on the following two-factor multiplicative index model:

$$Id_i = \frac{di_1}{di_0} = \frac{qi_1}{q_1} \div \frac{qi_0}{q_0} = \frac{di_1}{di_0} * \frac{q_0}{q_1} = Iq_i * \frac{1}{Iq};$$

$$Iq = \frac{q_1}{q_0};\ Iq_i = \frac{q_{i1}}{q_{i0}},$$

where di_1,di_0 - the share of the i-th product group in exports, respectively, for 2018 $_{(1)}$ та 2014$_{(0)}$ years.; $Id_i = \frac{di_1}{di_0}$ - index of change in the volume of exports of the *i* -th group for the period under study; $Iq = \frac{q_1}{q_0}$ - index of change in gross exports.

For example, in the first product group "Transport Services" the share of exports increased by 6,0% (Iq_1=9,29/8,77=1,06), but this growth is due to the fall in total gross exports by 10,3% (*Iq*=63,8/71,1=0,897), while the volume of exports of direct transport services decreased by 5.0% (Ig_1=5,92/6,23=0,95).

The generalized two-factor model of interrelation between factors of change of structure of export on this commodity group will be the following: Id_1=(5,92/6,23)/(63,8/71,1)=0,95/0,897=1,06 або 106,0%.

The determined factors of change of structure of distribution of export on all commodity groups are resulted in tab. 3.

TABLE 3. Factors of change in the commodity structure of exports in 2014-2018 *

Commodity group	Indices of change,% by 2014	
	specific weight (Id_i)	export volumes (Iq_i)
Transport services	106,0	95,0
Sunflower oil	132,0	118,9
Semi-finished products from iron or non-alloy steel	84,1	75,61
Corn	114,0	102,2
Wheat and meslin	124,0	111,4
ICT	41,6	37,3
Rolled flat of iron and non-alloy steel 600 mm or more	92,9	83,2
Insulated wires, cables and other electrical conductors	130,0	144,2
Cast iron	154,0	138,0
Ferroalloys	99,4	89,3
Total	-	89,7

* calculated by the author

The structure of Ukrainian industrial exports shows that the commodity content remains unchanged - raw materials and low-tech.

Indices of change in the share of each product group (Id_i) confirm the conclusions about the quality of industrial exports. For example, there is an increase in the share of cast iron by 54,0%, insulated wires and cables by 30,0% with a simultaneous significant decline in ICT exports (by 58,4%), while their direct volumes decreased by almost 63,0%.

According to the State Statistics Service of Ukraine, during 2010–2018 the share of exports of high-tech goods tended to decrease. In Ukraine there is a gradual decrease in intermediate goods export processing with 49,0% in 2010 to 44,7% in 2018 instead of the world average of 16,3% in 2017 (Figure 4.). All this reinforces the importance of implementing urgent actions to stimulate the export of products with a higher share of value added.

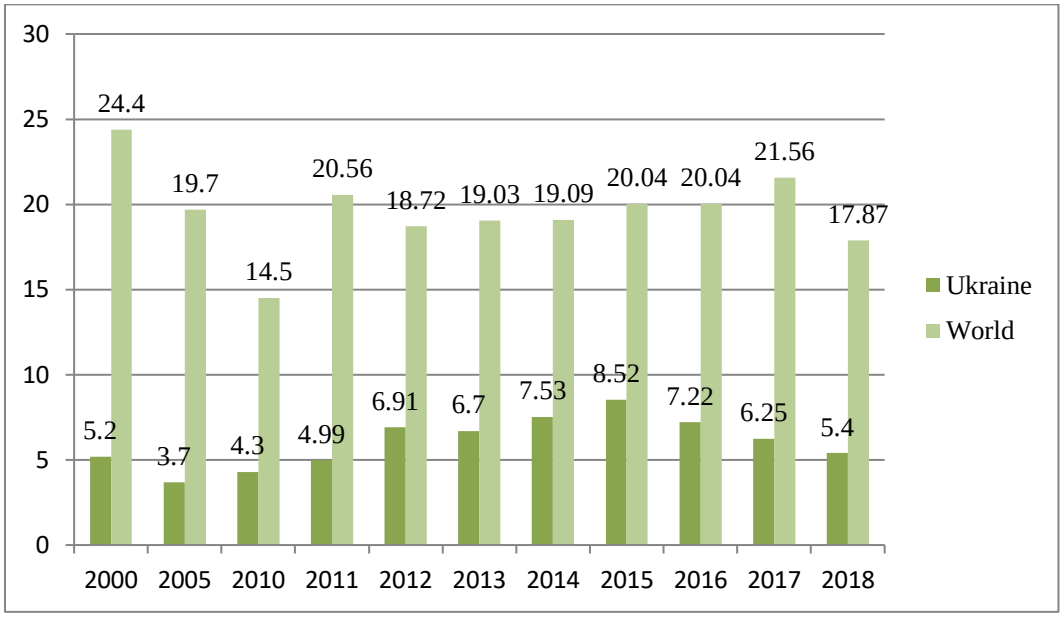

FIGURE 4. The share of high-tech exports in Ukraine and the world for 2010-2018,% of industrial exports [16]

In addition, there are growth trends in Ukrainian raw material exports - more than 70% of total industrial exports (low value-added products, including 30,7% - metallurgical products; 12% - wood, pulp and paper products, etc.) and increase in imports of high technology products (almost one-third increased imports of machinery), indicating that the technological lag in production of world figures. Given the current realities, it should be noted that the countries of the technological periphery do not have the opportunity to join the innovative achievements of technological leaders. Developed countries operate in the high-tech market, with the exchange of technologies between them. About 90% of the latest technologies are directed through internal corporate channels, which makes it possible to maximize the profits of multinational companies, to maintain their technological leadership.

Ukraine inefficiently uses the existing production and human resources, the existing system of research institutions engaged in basic and applied research, is poorly represented in world markets for high-tech products and even in the markets of traditional goods with a deep degree of technological processing, at the same time Ukraine is presented mainly as a supplier of raw materials and products with a low level of added value.

The export-oriented development model, in which the raw material component predominates in industrial exports (raw material exports account for 30,1% of total industrial exports, while exports of high-tech goods only 7,1%), has led to the fact that Ukraine is currently mainly production stages, which are characterized by capital intensity, low demand for domestic research and high-productivity workforce, disinterest in the development of related industries. This explains the insensitivity to innovation, the complexity of economic diversification [17]. Thus, Ukraine today is mainly competitive in the raw materials industry, and in order to survive in the context of the corona crisis it is necessary to move to higher levels of value chains.

The transition to Industry 4.0 is a new, important direction for Ukraine, and the first steps towards the development and adoption of regulatory framework in this area are already underway. Ukrainian producers found themselves in difficult conditions of survival: in 2019 there was a decline in industrial production, as evidenced by the following indicators: a decrease in the index of industrial production in Ukraine from 99,5% in 2019 to 95,5% in 2020; reduction of value added in industry from 26% in 2010 to 23% in 2018; negative changes in the commodity structure of exports, namely the growth of the share of raw materials and products with a low level of processing (the share of high-tech exports is gradually decreasing from 8,52% in 2015 to 5,41% in 2018); low level of reproduction of fixed assets of a significant share of enterprises (over 50%), etc. Despite the negative trends in Ukraine, there are successful cases for the development and implementation of Industry 4.0 technologies, but in general there is a low level of innovative development (in 2018, only 16,2% of industrial enterprises were engaged in innovation). In order to increase the complexity of the economy and industrial products produced in Ukraine, it is necessary to increase the innovative component of knowledge, technology and other know-how in the production of traditional industries, to develop high- and medium-high-tech industries.

Analyzing the value added of industry (Fig. 5), we can conclude that since 1990, Ukraine has only lost its position in industrial production and value creation, ie the competitiveness of goods and the degree of their processing decreased. At the same time, there is an increase in value added from its largest export partners: Germany, Poland, Turkey, India. The low added value of industrial production is an obstacle to the development of enterprises and their willingness to move towards Industry 4.0

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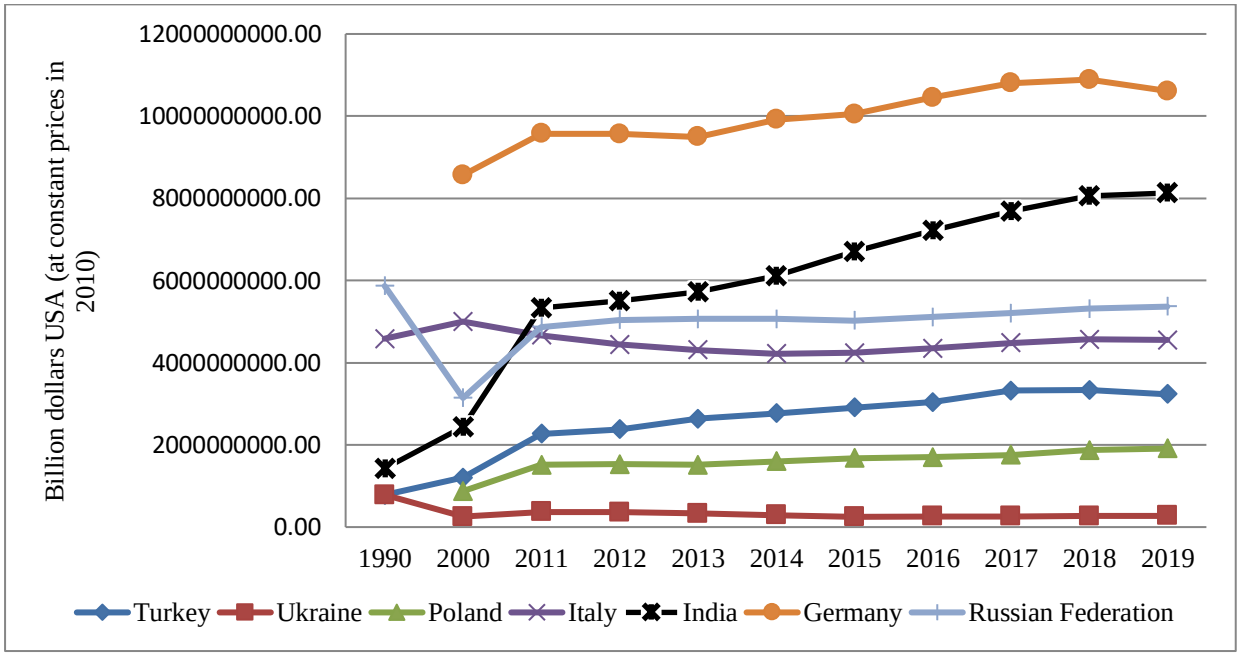

FIGURE 5. Dynamics of value added in industry of Ukraine and its export partners in 2019 (Industry (including construction), value added (constant 2010 US $) [18]

The process of transition of the country's economy to the format of Industry 4.0 involves the intensification of research and innovation activities at all levels of government. The World Bank evaluates the development of science and technology, innovation and technological development of countries on the following indicators: the number of scientists who carry out research and development (R&D); number of scientific journal articles; R&D costs; indicators of high-tech exports; the amount of fees from the use of intellectual property; the number of filed patent applications; the number of submitted applications for industrial design. Analysis of the dynamics of gross domestic expenditure on research in Ukraine shows that currently the results of research and scientific and technical developments have little effect on Ukraine's GDP growth. A linear model of innovative development has been formed in Ukraine, according to which the achievements of domestic science have not yet become technological drivers. In recent years, Ukraine has spent an average of 0,62% of GDP on science, of which about a third went to public funding, and the rest was financed from other sources. According to the Global Competitiveness Index, 0,4% of GDP was spent on science in 2018, 0,45% of GDP in 2017, while, for example, in Germany – 2,94%, Italy – 1,29%, USA – 2,74%, Great Britain – 1,69%, Norway – 2,03%, Poland – 0,97%, Turkey – 0,88%, the Russian Federation – 1,10%, Belarus – 0,59%, in India – 0,62%, which shows that the development of intellectualization processes requires an increase in R&D expenditures. In 2018, the total budget funding for strategic priorities of innovation and technology transfer activities amounted to 94,9% of the total budget funding for innovation, which is 12,5% more than in 2017, Ukraine lags behind the European figure for 2,03%. This situation is confirmed by the indicators of innovative development of Ukraine, shown in Fig. 6, Fig. 7.

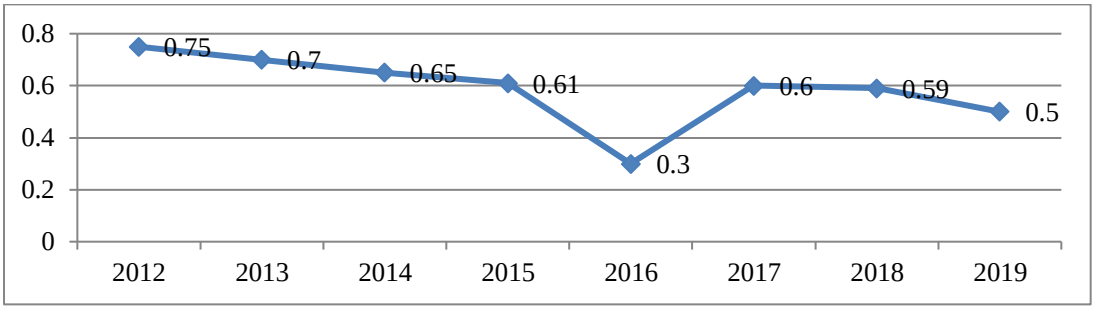

FIGURE 6. Science-intensive gross domestic product of Ukraine, % [12]

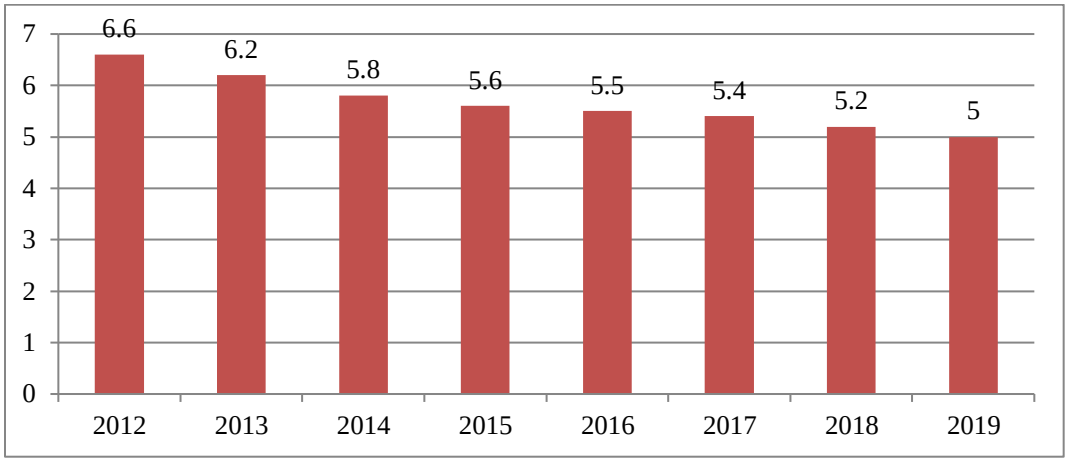

FIGURE 7. The total number of research staff in Ukraine per thousand full-time equivalents [19]

Regarding high-tech exports of Ukraine, according to the World Bank, it has extremely low figures: only 1248 million dollars, of which industrial exports account for 5,4%. For comparison: in Germany, the volume of high-tech exports is 209610 million dollars (of which 15,8% - industrial); USA – 156366 (18,9% - industrial); Italy – 33821 (7,7% - industrial); Great Britain – 76533 (2,6% - industrial); Norway – 4295 (21,2% - industrial); Poland – 22237 (10% - industrial); Turkey – 3117 (2,3% - industrial); RF – 10183 (11,0% - industrial); in India – 20273 million dollars (of which 9,0% - industrial) [20].

The Global Innovation Index (GII), which is calculated according to the methodology of the International Business School INSEAD in France, is an aggregate indicator of the level of innovation development, as well as factors of innovation and technological development. This index consists of 80 indicators for 129 countries, which describe in detail the innovative development of the world.

In 2019, Ukraine ranked 47th among 129 countries according to this index (Fig. 8).

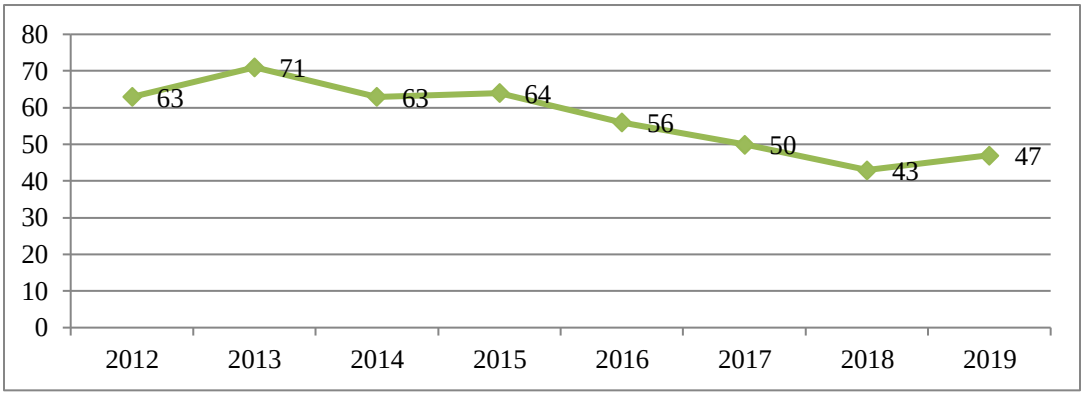

FIGURE 8. Ukraine's place in the Global Innovation Index [12]

It should be noted that the first sub-index of innovation, which characterizes the state of development of institutions; human capital and research; infrastructure; domestic market development; business development (Innovation Input) - 82nd place, second, which allows you to assess the development of technology and knowledge economy, the results of creative activity (Innovation Output) - 36th place in the ranking [21]. Such results indicate insufficient conditions for the creation and implementation of innovations, in particular in enterprises. At the same time, the leading world rankings determine the high level of the intellectual component of human capital in Ukraine. Thus, according to the study HUMAN CAPITAL INDEX, Ukraine ranked 50th in the ranking of the quality of human capital, receiving 0,631 points in 2020. With this figure, the Ukrainians bypassed Turkey, Albania, Montenegro and Qatar, but lost to Hungary, Slovakia and Russia [19]. Ukraine has a strong scientific and scientific-technical potential, well-known scientific schools and outstanding scientific achievements, which are concentrated in the academic, university and branch spheres.

Based on the above, it should be noted that despite the insufficient level of funding for science, Ukraine is in the first half of the Global Innovation Ranking and has strong scientific potential, however, the number of inventions, number of researchers and number of scientific publications are important indicators of innovation, but do not affect the innovative success of industrial development. In order to introduce innovative transformations in the industry, realized inventions and commercialization of scientific developments are necessary, the key driver should be the improvement of the innovation infrastructure to stimulate the attraction of capital in specific innovative projects.

Thus, the development of Ukrainian industry as the main driver of economic growth in modern conditions is influenced by a combination of negative factors and has complex problems, but can potentially realize its potential in the new technological challenges of Industry 4.0.

CONCLUSIONS

Studies have shown that, globally, there is a need to revitalize and modernize industry in line with the concept of Comprehensive and Sustainable Industrial Development (ISID), and the benchmark for many countries is the fourth industrial revolution (Industry 4.0). The potential of Ukrainian industrial enterprises for intellectualization in the direction of Industry 4.0 is significantly reduced. Industry in Ukraine is experiencing a systemic crisis. In terms of readiness to implement leading technologies, Ukraine ranks in the global rankings and is estimated to be a country with a limited production base and the absence of significant factors for the introduction of new technologies. To improve Ukraine's position in the global innovation rankings, it is necessary to focus on creating an effective system of state incentives for digital development of domestic industry, which would include support for science and innovation, creating favorable conditions for domestic producers and strengthening strategic partnerships.

Ukraine exports mainly products that do not require complex know-how in production, products with low added value (raw materials and semi-finished products). To increase the complexity of industrial products produced in Ukraine, it is necessary to increase the innovative component of knowledge, technology and other know-how in the production of traditional industries, to develop high- and medium-high-tech industries. R&D expenditures are insignificant compared to other countries in the world. All this indicates that modern vectors of world industrial development are mostly a challenge to the capabilities and readiness of Ukrainian industry. Therefore, the revival of industry and ensuring the competitiveness of industrial enterprises in domestic and foreign markets should become one of the priorities of national economic development.

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