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Dominants and Features of Growth of the World Market of Robotics

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Purpose: Explore the current state, trends and development prospects of the global robotics market, especially the industrial robotics segment, as well as the service robots segment.

Design/Method/Approach: Logical, statistical, and graphical methods were used; systemic, structural-functional, and comparative types of analysis. The specificity of the interdisciplinary research is expressed in the use of the methodology for graphical presentation of the life cycle of technologies and goods.

Findings: The format for the use of “end-to-end” digital technologies, which include robotics, artificial intelligence and others, was determined, which leads to extreme changes in production and consumption and, in fact, marks the onset of a new technological order. It can be stated that a new cluster of innovations has been formed in the information technology industry, going beyond its limits, explosively transforming the sectors of the economy, the activities of the state and business, society, and the world as a whole. The world markets for new technologies and goods are being formed, the composition and distribution of the roles of the participants in the global innovation system are changing. Modern concepts of innovative development of the world economy were studied, and a comparative analysis of methods for studying the markets of high-tech goods in various schools of economics was carried out. The authors outlined the features of the formation of the world robotics industry as a large technological system and assessed the place of the world market of robots in the world economy. The study contains the results of the work carried out to study the conditions and factors of the development of the global robotics market, as well as an overview of its geographical and corporate structure. In the scientific work, a study of the features of pricing in the robotics market and the specifics of creating and financing robotic projects was carried out.

Theoretical Implications: A comprehensive assessment of the global robotics market was carried out and the leading vectors of its transformations and growth prospects were identified.

Practical Implications: The obtained results of the study can be used as the basis for the formation of a corporate strategy for the development of individual companies and enterprises of industrial sectors of the world economy in order to accelerate innovative, technical and economic development in a durable format.

Originality/Value: The features and components of the development of the world industrial robotics market have been investigated. The encouraging directions of robotization of the world economy are determined. Prospects for further research. The obtained results can be used in the context of the promising development of a national doctrine or policy of robotization and the development of digital robotic systems of industry in the countries of the world.

Future Research: The obtained results can be used in the context of prospective development of national doctrine or policy of work and development of digitalized industrial systems of the world's countries.

Paper type: Theoretical

Keywords: world economy, world market of robotics, robotics companies, industrial innovation, world industry.

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Домінанти і особливості зростання світового ринку робототехніки

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Мета роботи: Дослідити сучасний стан, тенденції та перспективи розвитку світового ринку роботів, особливо сегменту промислової робототехніки, а також сегмента професійних сервісних роботів.

Дизайн/Метод/Підхід дослідження: Використано логічний, статистичний і графічний методи; системний, структурно-функціональний і порівняльний види аналізу. Специфіка міждисциплінарного підходу дослідження виражена у використанні методології графічного уявлення життєвого циклу технологій і товарів.

Результати дослідження: Було визначено формат застосування «наскрізних» цифрових технологій, до числа яких відносяться робототехніка, штучний інтелект і інші, призводить до кардинальних змін виробництва і споживання і, по суті, знаменує настання нового технологічного укладу. Можна констатувати, що сформувався в індустрії інформаційних технологій новий кластер інновацій, вийшовши за її межі, підірваним чином трансформує галузі економіки, діяльність держави та бізнесу, суспільство і світ в цілому. Формуються світові ринки нових технологій і товарів, змінюються склад і розподіл ролей учасників глобальної інноваційної системи. Були досліджені сучасні концепції інноваційного розвитку світової економіки, а також проведений порівняльний аналіз методик вивчення ринків високотехнологічних товарів в різних економічних школах. Авторами викладено особливості формування світової індустрії робототехніки як великої технологічної системи і надана оцінка місця світового ринку роботів в світовій економіці. Дослідження містить результати проведеної роботи по вивченню умов і факторів розвитку світового ринку робототехніки, а також огляд його географічної й фірмової структури. В межах наукової роботи проведено дослідження особливостей ціноутворення на ринку робототехніки та специфіки створення і фінансування робототехнічних проектів.

Теоретична цінність дослідження: Проведене комплексне оцінювання світового ринку робототехніки та визначено провідні вектори його трансформацій і перспектив зростання.

Практична цінність дослідження: Отримані результати дослідження можуть бути покладені в основу формування корпоративної стратегії розвитку окремих компаній і підприємств промислових секторів світової економіки з метою форсування інноваційного, технічного і економічного розвитку у сталому форматі.

Оригінальність/Цінність дослідження: Досліджено особливості та компоненти розвитку світового ринку промислової робототехніки. Визначено перспективні напрямки роботизації світового господарства.

Майбутні дослідження: Отримані результати можуть бути використані в контексті перспективної розробки національної доктрини або політики роботизації і розвитку цифрових роботизованих систем промисловості країн світу.

Тип статті: Теоретичний

Ключові слова: світова економіка, світовий ринок робототехніки, робототехнічні компанії, промислові інновації, світова промисловість.

Доминанты и особенности роста мирового рынка робототехники

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Цель работы: Исследовать современное состояние, тенденции и перспективы развития мирового рынка робототехники, особенно сегмента промышленной робототехники, а также сегмента сервисных робототехники.

Дизайн/Метод/Подход исследования: Использованы логический, статистический и графический методы; системный, структурно-функциональный и сравнительный виды анализа. Специфика междисциплинарного подхода исследования выражена в использовании методологии графического представления жизненного цикла технологий и товаров.

Результаты исследования: Было определено формат применения «сквозных» цифровых технологий, к числу которых относятся робототехника, искусственный интеллект и другие, приводит к кардинальным изменениям производства и потребления и, по сути, знаменует наступление нового технологического уклада. Можно констатировать, что сформировался в индустрии информационных технологий новый кластер инноваций, выйдя за ее пределы, взрывным образом трансформирует отрасли экономики, деятельность государства и бизнеса, общество и мир в целом. Формируются мировые рынки новых технологий и товаров, меняются состав и распределение ролей участников глобальной инновационной системы. Были исследованы современные концепции инновационного развития мировой экономики, а также проведен сравнительный анализ методик изучения рынков высокотехнологичных товаров в различных экономических школах. Авторами изложены особенности формирования мировой индустрии робототехники как большой технологической системы и дана оценка места мирового рынка робототехники в мировой экономике. Исследование содержит результаты проведенной работы по изучению условий и факторов развития мирового рынка робототехники, а также обзор его географической и фирменной структуры. В научной работе проведено исследование особенностей ценообразования на рынке робототехники и специфики создания и финансирования робототехнических проектов.

Теоретическая ценность исследования: Проведено комплексное оценивание мирового рынка робототехники и определены ведущие векторы его трансформаций и перспектив роста.

Практическая ценность исследования: Полученные результаты исследования могут быть положены в основу формирования корпоративной стратегии развития отдельных компаний и предприятий промышленных секторов мировой экономики с целью форсирования инновационного, технического и экономического развития в постоянном формате.

Оригинальность/Ценность исследования: Исследованы особенности и компоненты развития мирового рынка промышленной робототехники. Определены перспективные направления роботизации мирового хозяйства. Перспективы дальнейших исследований. Полученные результаты могут быть использованы в контексте перспективной разработки национальной доктрины или политики роботизации и развития цифровых роботизированных систем промышленности стран мира.

Будущие исследования: Полученные результаты могут быть использованы в контексте перспективной разработки национальной доктрины или политики роботизации и развития цифровых роботизированных систем промышленности стран мира.

Тип статьи: Теоретический

Ключевые слова: мировая экономика, мировой рынок робототехники, робототехнические компании, промышленные инновации, мировая промышленность.

1. Introduction

The innovative development of the world economy is a complex and multifaceted process. A deep and versatile understanding of this phenomenon is an important prerequisite for the correct analysis of such a high-tech industry as the global robotics market. At the present stage, robotics, which was once still an attribute of science fiction works, is becoming an integral element of globalized technical and economic life. Robotics today is a global industry that is rapidly developing. So, the work has been already widely used in manufacturing, defense, space research, medicine, education, and other areas. Researchers are optimistic about the prospects for this area of applied innovation. Thus, the consulting company “Boston Consulting Group” (BCG) predicts the growth of the volume of the profile world market of robotics until 2025 up to \$ 87 billion (BCG, 2021). The industry publication “Robotics Business Review” cites the forecast of the International Federation of Robotics, according to which sales of industrial robots will grow annually by 10-12% to a level of 584,000 new devices already in 2022 (Robotics Business Review, 2021). In the context of the onset of a new technological order, global modernization and automation of production and other areas of activity, the competition of the world's leading states for leadership in the robotics market forms a high level of relevance of research in this area of the world economy.

2. Literature Review

In the context of this scientific work, the concept of large technological systems by the technology the historian, professor at the University of Pennsylvania Hughes is being of particular interest. Hughes refers to large technological systems as “a complex set of different components aimed at solving a specific problem” (Hughes, 1987). Among the components of such systems, the researcher proposes to include not only the so-called “physical artifacts” (raw materials, equipment, products, etc.), but also organizations – production, sales and other enterprises, banks, as well as other elements: scientific programs, training of personnel, specialized state regulation. According to Hughes, large technological systems in their development usually go through the stages of invention, development, innovation, transfer, growth, competition, and consolidation.

In the works (Landscheidt et al., 2018; Abhijit, 2020; Ross & Maynard, 2021) it is stated that the design of robots is an interdisciplinary field that covers such areas as machine vision, navigation, energy, communications, sensors, control systems, drives, transceivers, on-board computers and other systems are dynamically developing both in the context of the development of robots and as independent disciplines, it seems possible to consider robotics as an example of a cluster of innovations, a large technological system and basic technology simultaneously.

A significant contribution to understanding the nature of innovative development was carried out by Harvard Business School Professor Christensen, who proposed the concept of “disruptive” innovation. As Christensen explains, most new technologies drive product improvements. According to the characteristics proposed by Christensen, certain categories of robotics can be considered as “disruptive” technologies (Christensen, 2011). Industrial robots have been available in the market for a long time – innovations in this area are supportive. At the same time, applications in various fields of service robotics are growing today. Such devices are still far from ideal, but their consumer base is steadily growing, and it is they who have “disruptive” potential.

Special attention should be paid to the views on the innovative development of the world economy of the founder and president of the World Economic Forum in Davos, a German economist, Professor Schwab. He states that “today we are at the origin of the

fourth industrial revolution” (Schwab, 2017). The independence of this stage is substantiated by Schwab by three factors: 1) the exponential pace of technology development, 2) the combination of the breadth and depth of the current transformations, and 3) the systematic impact on countries, companies, and society. The technological base of the fourth industrial revolution includes artificial intelligence (AI), blockchain, 3D printing, biotechnology, the Internet of Things, as well as robotics and unmanned vehicles. The researcher points out that if earlier robotics was in demand only in several industries for the implementation of certain operations, then at the present stage the scope of application of robots is constantly expanding.

For the purposes of this work, it will be very useful to consider the concept of a global innovation system considered in the works (Binz & Truffer, 2017; Cooke, 2017; Li, Hou, & Wu, 2017; Makedon, et al., 2019b). So, the modern global innovation system is a three-tier system. The center consists of the United States, Western Europe, and Japan, collectively, they support the production of explosive, basic technology platforms, as well as some advanced goods and services. In other words, the center is focused on high-margin types and stages of innovation activity, forcibly giving the other to the periphery of the global innovation system and the concentration of resources on tools to maintain leadership. Semi-peripheral countries include countries that develop incremental innovations to support current technologies and manufacture components. These are countries such as the Republic of Korea, Singapore, Taiwan, China. In fact, these countries differ from the center in their inability to produce their own disruptive innovations or basic technology platforms. The periphery covers countries that specialize in less marginal areas of activity – the production of primary components, screwdriver assembly and the like. These states include the Philippines, Indonesia, Malaysia.

3. Purpose of the study

Identify the key areas of development of the global robotics market and determine the strategic and organizational prospects for its development under the influence of the current technological order and digitalization of the global economic system.

4. Data and methods

The market is a multifaceted phenomenon, “a complex system of relationships between various entities regarding the sale of goods”. The processes taking place in high-tech markets can influence the economy and development of society at the national and global levels. Given the complex, interdisciplinary nature of the robotics industry, as well as the global robotics market, the study of the latter requires a careful study of a few methodological and theoretical-applied approaches.

1. Methodology of civilizational measurement. It has been determined that new technologies underlying technological structures determine the structure of the economy and civilization in a given period. Currently, a new post-industrial technological mode of production is being formed in the world economy. In this context, the scientist predicts the humanization of technologies. One of the most important areas of this process is automation, robotization and informatization of production, freeing a person from heavy physical and monotonous labor, which leaves him with intellectual functions for the development, design, and creation of systems of machines, technologies, and control systems for their functioning.

2. Methodical approach – “NBIC-convergence”. In the last 10 years, the concept of the Industrial Internet of Things (IIoT) has become widespread: a system of interconnected computer networks and connected industrial (production) facilities with built-in sensors and software for collecting and exchanging data, with the possibility of remoting control and management in an automated mode. Robotics has become a key component of various initiatives

related to the digitalization of production, the introduction of cyber-physical systems. The solution of pressing economic and social problems of our time could be facilitated by the development of nature-like technologies based on the synergy of the achievements of nano-, bio-, information and cognitive sciences (NBIC-convergence). As noted by Panetta (2019), McGinnis (2020), the essence of creating a nature-like technosphere is “the restoration of the natural resource harvest disturbed by modern technologies taken out of the natural context”. Cognitive research, based on the study of consciousness, human mental activity, makes it possible to develop algorithms for the “animation” of the created robotic systems.

3. Model of the life cycle of innovation and robotics. The methodology provides a graphical representation of the technology life cycle, demonstrating the dynamics of changes in consumer expectations over time. The technology life cycle spans five stages (Schulze, 2019):

- Innovation Trigger. Against the background of the invention of new technology, information about it is actively disseminated in the media. Often, working prototypes of a product are not available, and its commercial value has not been proven.
- Peak of Inflated Expectations. Some companies start production, the first success and failure stories appear, but most are not yet operational.
- Trough of Disillusionment. Interest in technology is dwindling because of increasing setbacks. Several enterprises are forced to abandon development to avoid ruin. Only those companies that modernize their product to retain the first users manage to keep the inflow of investments.
- Slope of Enlightenment. New ways of applying the technology are becoming known. Manufacturers release the second and third generation of their products. A growing number of companies are launching relevant pilot projects.

- Plateau of Productivity. There is massive adoption of the technology. Manages to formulate the criteria more clearly for the viability of the manufacturing company. The technology is starting to pay off.

The use of this methodology makes it possible to assess the prospects of a particular technology more accurately on the market, reducing the distracting influence of the information background.

5. Results

It is advisable to study the conditions and factors for the development of the world robotics market in comparison with other markets that are similar in nature, such as the market for information technology products, cars, mechanical engineering products, as well as in conjunction with the dynamics of development of the main consumer industries of robotic devices.

5.1. The place of robotics in global industrial sectors

The specialized publication “Gartner” annually publishes relevant analytical materials, both in general on new technologies, and in refraction for specific industries, such as artificial intelligence or digital government. So, in relation to robotics, the review of promising technologies for 2020 is of scientific interest below (Fig. 1). To simplify perception, only technologies that may have a potential impact on the development of the robotics market in 2030 are left on the chart.

Figure 1: Gartner Hype Cycle for Advanced Technologies in 2030

Source: JEITA (2020)

Important factors determining the demand for industrial robots are the state of the world economy and the dynamics of development of key consumers of robotics – enterprises of the global automotive industry and the electrical / electronic industry. The relevant provisions and statistics are graphically presented in Fig. 2.

Figure 2: Production of industrial robots versus vehicle production 2010-2020

Source: IFR (2020a); International Organization of Motor Vehicle Manufacturers (2021)

In Fig. 2 the volume of production of industrial robots in the period 2010-2020. Presented in comparison with the volume of production of passenger cars. This chronological trend was chosen to demonstrate the dynamics of both industries in the context of the global economic crisis of 2008-2009, as well as in the years of recovery after it. The results of the analysis show that the phases of growth and decline in the production of robotics and cars coincide, and depend on the general state of the world economy. Data for 2019 indicate that the global economic crisis had a negative impact on the demand for the products of the global automotive industry, which, in turn, led to a decrease in interest in investments by automakers in robotics and led to a decline in the profile market.

As evidenced by the results of research International Finance Corporation (IFC), after the economic crisis of 2008-2010 global automakers have begun restructuring their businesses. Beginning in March 2011, amid recovering demand for cars, automakers' investments in production in regions of the developing world, as well as modernization of factories in leading countries of the automotive industry, supported the demand for robotics. Increased technological competition among market leaders has fueled increased investment in R&D and innovative production transformation. Between 2012 and 2019, the Compound Annual Growth Rate (CAGR) for the automotive industry was around 13% annually.

To compare the growth dynamics of the industries of production of electrical / electronic products, as well as industrial robotics, Fig. 3 showing the corresponding indicators for the period from 2010-2020 are shown.

Given the wide variety of nomenclature in the electrical / electronics industry, the comparison with industrial robotics is not in the number of units of products, but in value terms. As in the case of the automotive industry, the graphs show that the dynamics of the two industries coincide, and their dependence on events in the global economy can be traced. So, the crisis of 2008-2010 caused a decline in sales of electrical / electronic products, in turn, it also negatively affected the demand of the industry enterprises for industrial robotics. The average growth rate of sales of robots in all industries, except for the automotive industry and the electrical / electronic industry, was 17% from 2012 to 2017. This demonstrates that robotics companies have been offering more and more versatile solutions that appeal

not only to traditional consumers, but also to other customers in the manufacturing industry.

Figure 3: Sales of industrial robots versus sales of electrical / electronic products 2010-2020

Source: IFR (2020a); Statista Research Department (2021)

In general, since 2011 the demand for industrial robots has increased significantly due to the continuing trend of automation and continuous improvement of such devices. Against the background of investment recovery after the crisis in 2012-2017 sales volumes doubled and averaged about 234,000 units for a year. During this period, the cumulative average annual growth in sales of robotics has already reached the level of 18.7% per year. Moreover, for the period from 2015 to 2018, the average annual growth was about 300,000 units, which became a demonstrative sign of the rapidly growing demand for industrial robots on a global scale (Statista Research Department, 2021).

5.2. Pattern Matrix of hierarchical constructs

In present time, Asia is the fastest growing robotics market in the world. In 2019, a total of about 284,000 different robots were sold in the region. This is yet another top selling, recorded for the sixth consecutive year. In the previous period, from 2012 to 2018, the number of robot installations in Asia grew by an average of 19% annually. Sales of industrial robots in the second largest market in the European Union increased by 10.6% annually and reached the level of 75,000. Another high in the previous six years, and the CAGR between 2012 and 2018, when and in the US market was about 9%. In 2018, about 55,000 industrial robots were sold to businesses in the Americas, up 15.8% from a year earlier, also hitting a new high in the past six years. Visual dynamics is shown in Fig. 4.

Figure 4: Sales of industrial robots in the world by region, 2012-2020 and forecast for 2021-2022

Source: Research and Markets (2021)

For example, 73% of total global robotics sales in 2019 came from five main markets: China, Japan, USA, South Korea, and Germany. Below are the results of the analysis of the dynamics of consumption of industrial robotics among the leading countries, the ratio of which is shown in Fig. 5.

Figure 5: Sales of industrial robots by country in 2020

Source: WIN News (2021)

Since 2013, China has been the largest continuously and dynamically growing robot market in the world. According to the International Federation of Robotics (IFR), China has significantly increased its leading position as the largest market with a 37% share of total sales in 2020 (up from a year earlier). About 154,000 industrial robots were sold in the PRC in 2020. This figure significantly exceeds the total sales in Europe, as well as in the states of North and South America combined (132,000 units). At the same time, the China Robot Industry Alliance (CRIA) provides other data, according to which, in 2020 there was a decline in sales of industrial robotics in China – 130,000. The mismatch appears to arise from differences in the scoring methodology of the two organizations and may also be related to the difference in the estimates of the impact on the industry of the trade war between China and the United States (*Executive Summary World Robotics, 2020*).

Sales of robots in Japan in 2020 grew by 20.8% to 55,000, which is a record figure for the entire period of conducting relevant statistics in the country. Since 2013 the consumption of robotics by Japanese enterprises has shown a steady growth of 18% annually. Note that such dynamics is observed against the background of the previously achieved high level of production automation. The main source of growth in recent years has been the electrical / electronic industry, while the share of the automotive industry has remained largely unchanged. In 2012-2017 sales of robots in Japan grew by an average of 11% annually. Japan is also a global leader in robotics manufacturing, accounting for 51.5% of global robotics exports in 2020.

The number of sales of robots in the United States continues to grow and in 2020 (for the ninth year in a row) reached another record – over 41,000, which is 22% higher than in 2019, which preceded the COVID-19 pandemic. Since 2011, the driving force behind growth in all manufacturing industries in the United States is the trend towards automation to strengthen the position of American manufacturing in both domestic and global markets (*Makedon, et al., 2020*). So, the United States was able to bypass the Republic of Korea, taking third place in the world in this indicator.

Sales of robots in the Republic of Korea decreased by 5% to the level of 37,000. In 2020 the decline continues for the second year in a row due to the consequences of the COVID-19 pandemic. The robotics market in the country is focused primarily on the electrical / electronic industry, whose enterprises have experienced difficulties in recent years. Earlier in 2012-2017 sales of robots in the Republic of Korea have increased by an average of 13% annually.

Germany is the fifth largest robotics market in the world and the first in Europe. In 2020, the number of sold robots reached a new high of more than 26,000, which is 25% more than in the previous

year. The key consumer of robotics devices in the country is the automotive industry.

The International Federation of Robotics singles out Taiwan in its statistics on the most Asian markets. According to this federation, since 2013 Taiwan has been the sixth most important robotics market in the world in terms of annual shipments. So, in the period from 2012 to 2018 the number of sales of robotic devices increased significantly – by an average of 27% annually. In 2020 sales of robots amounted to about 12,100, which marked a new record. The source of growth, as in previous years, was the electrical / electronic industry. India has managed to achieve serious success, increasing its annual sales of robots by more than 41% to 4,900. At the same time, Singapore gave way to India, with a slight decline to about 4,320 at the end of 2020, which still did not prevent the country from being among the top 15 robotics markets in the world. A slight decrease to 3,300 units (in 2019 – 3,400) was observed in Thailand, which closes the list of Asian countries in this ranking (*International Federation of Robotics, 2021*).

IFR lists Italy, France, Spain, and the Czech Republic as major European markets. In Italy, for example, investment in robotics has continued to grow, leading to a market growth of 26% to a new record high of 9,800 robotic products. The French robot market also showed moderate growth to a new high of about 5,800. Positive dynamics was also observed in Spain, where sales of industrial robots also reached a new record – 5,300. Sales of robotics grew in other European countries in the Czech Republic, where the number of delivered devices amounted to 2,700, which ensured the country entry into the list of leading markets for robotic devices.

5.3. Analytical study of changes in the global robotics market

In recent years, Singapore has always been one of the leaders in terms of robotics. According to IFR, the reason for this result, along with the high level of technological development of the country, was also the small total number of workers in the manufacturing industry – only 240,000 people according to the International Labor Organization. At the same time, about 85% of robots in Singapore are installed in enterprises producing electronics. Since 2011 and until 2019 the Republic of Korea occupied the first place in terms of the density of robotization in the manufacturing industry. The corresponding figure in the country has been rising steadily since 2011 (312 devices / 10,000 workers) due to the continued installation of a large number of robots, especially in the electrical / electronic and automotive industries. Germany and Japan follow closely behind, with just over 300 devices per 10,000 industrial workers. While Japan had the highest density of robotization in the world in 2010, the Republic of Korea since 2011, Singapore since 2016, and since 2018 Germany has surpassed the country in the corresponding ranking. Attention is drawn to the fact that the density of robotization in Japan in 2010. It amounted to 332 units, and in recent years there has been a decrease in the agenda of 297 devices, which does not correspond to the global dynamics of development. China is showing significant growth. If in 2010 in the country, there were 9 robots per 10,000 workers in the manufacturing sector, then over the past decade this figure has increased more than ten times to 112 units per 10,000 workers (*IFR, 2020b*) (Fig. 6).

The level of automation in the automotive industry is generally much higher than in all other sectors. Since 2014 a significant number of industrial robots have been delivered to the enterprises of the South Korean automotive industry. Already in 2017, in the Republic of Korea, there were 2,432 industrial jobs per 10,000 workers, double the corresponding figure in 2010 (1234 devices). According to IFR experts, large-scale projects to produce batteries for hybrid cars and electric vehicles may be the source of such a significant increase in the density of robotization.

Figure 6: Density of Manufacturing Robotics by Country in 2020

Source: International Federation of Robotics (2021)

Other leading countries in the automotive industry are also characterized by a high density of robotization of the industry-specific: the United States – 1200 units, Germany – 1161, Japan – 1157, France – 1155. By the end of 2020, all of them exceeded the “psychological” mark of 1,000 robots by 10,000 employees (IFR, 2020b).

The density of robotization in other global industries is still relatively low. However, countries with developed electronic production rank higher in this indicator. The leader in 2020 was the Republic of Korea with 532 jobs per 10,000 workers, followed by Japan with 224 jobs, Germany with 192 and Sweden out of 181 devices. As noted by IFR experts, in Germany and Sweden there are no production sites in the electronics industry compared to Asian ones. The relatively high figure in both countries is due to the more diversified distribution of industrial robots across all sectors of the national economy. A further increase in the automation of the production of electronic devices will contribute to an increase in the number of installations of robots in the corresponding production centers, primarily in Asian countries (Fig. 7).

Figure 7: Number of industrial robots sold by the world's leading robotics companies since their inception (total for 2020)

Source: Statista Research Department (2021)

The difference between the rate of implementation of robotics in the automotive industry and other manufacturing industries in these countries of the world demonstrates the significant potential for the installation of robotic devices. Even in the Republic of Korea, the density of robotization in the general industry is just under one-fifth of that in the auto industry. The potential for installing robots is also high in the automotive industry in emerging and some traditional markets (*Executive Summary World Robotics, 2020*). Moreover, the ongoing modernization and re-equipment of production facilities also guarantee further investments in robotics in countries that have already reached a high level of automation.

Certain changes in the list of leaders are possible in the event of the movement of production facilities abroad, but it is unlikely that this will affect the total volume of investments in robotics. At the same time, the cumulative number of installed robotics devices during the existence of companies was estimated based on data as of mid-2020 (Digo, et al., 2020). The presented graph demonstrates that the leadership in the industrial robotics market belongs mainly to companies from Japan, Germany, Switzerland, and the United States.

The authoritative profile resource “Robotics Business Review” (RBR) uses a different methodology to assess the corporate structure of the market. Considering the dynamic change in the situation in the industry and its interdisciplinary nature, the analysts of the publication compile the annual RBR-50 rating from 50 companies that have made a decisive influence on the development of various fields of robotics this year.

The information provided by the Robotics Business Review (2021) resource testifies to the formation of the most demanded directions in the robotic market today. These include industrial robots, collaborative robotics, robotic solutions in the field of warehouse logistics and robots for inventorying goods in stores, as well as medical robotic devices. Most of these areas relate to professional service robotics. It is noteworthy that most of the companies included in the rating are of American origin. The diverse nature of the solutions presented allows us to speak about the formation in the United States of a scientific and technical groundwork for leadership in the professional service robotics market. In general, the above data indicate that a relatively stable group of leading countries in the production and consumption of robotics has already formed in the global robotics market: China, USA, Japan, Germany, Republic of Korea, Singapore, Switzerland, Sweden, Denmark, etc. (*Global Robot Report, 2021*). The general growth in the interest of companies from leading countries in the field of robotics in patenting specialized inventions is clearly illustrated in Fig. 8.

Figure 8: Number of robotics patent applications first filed by country of origin, 1960-2019

Source: Statista Research Department (2021)

At the present stage, the foundations of the geographical specialization of countries in the market of robotic devices continue to be laid. So, in industrial robotics, Japan, Germany, and Switzerland occupy leading positions, while professional service robotics is successfully developing in the United States.

It should be noted that in the future, the list of the largest robotics markets may undergo changes. Uncertainties that are likely to negatively affect the global robotics market are the continuing trade disputes between the United States and China, the COVID-19 coronavirus infection pandemic in 2020, and general macroeconomic instability.

Given the high science intensity of production and the need for significant investment in R&D, robotics companies are striving to

consolidate their monopoly position in certain niches of the specialized market. The preservation of technological rent is ensured by manufacturers of robotics through patent protection, ensuring a trade secret regime to preserve know-how (production secrets), and attract and retain unique specialists. Significant costs for patenting, as well as technological rent, are reflected in the final price of the product (Makedon, et al., 2019a). The price of a specific industrial robotics device largely depends on characteristics such as load capacity, range, purpose, availability of special working bodies. To use the robotic complex, you may additionally need peripheral equipment, consumables, and services of specialized companies-integrators for the implementation of technology, taking into account the unique characteristics of the customer. A manufacturer or integrator may also face the challenge of organizing and performing maintenance and warranty repairs for robots (Takeda, Carbone, & Bai, 2020).

Large global robotic companies usually do not publish prices for their devices in the public domain, but provide on demand, motivating this approach by the need for an individual calculation, considering the needs of a particular customer.

At the same time, the approximate price range can be estimated by studying materials from open sources. So, on the B2B trading platform "Alibaba.com" prices for industrial robots vary from 1,000 to 150,000 dollars. US per device depending on device configuration. The Made-in-China.com portal offers a wide range of Chinese industrial robotics with an average cost of \$ 1,000 to \$ 120,000 US dollars for one robot on FOB terms. According to the German company for the analysis of market statistics "Statista", the average price for one device of industrial robotics in 2020 amounted to 47,000 US dollars (Statista Research Department, 2021). The dynamics of the world average price of one industrial robot from 2011 to 2020 is shown in Fig. 9.

Figure 9: Dynamics of changes in the average price of an industrial robot in 2011-2020

Source: IFR (2020b)

It is advisable to consider the problem of pricing robotics from both the manufacturer and the consumer, since often the final price for industrial and service robots, given the uniqueness of specific technological solutions and the complexity of their implementation, is determined in the interaction of the customer with the developer or integrator. A significant role for potential buyers in assessing the need to purchase robots is represented by such an indicator as the price of consumption of robotics, which consists of the cost of purchasing devices and the cost of operating them.

In the case of industrial robotics, it is also important to take into account the net effect of its use, which is the sum of the cost of production and the price of consumption of machines. Accordingly, the use of robotics devices should lead to a decrease in the cost of production, then investments in the modernization of production will be profitable and will be expedient.

6. Conclusions

It was determined that through the pervasive nature of robotization, the concern of the world community with the problems of technological and structural unemployment is growing. In this context, it should be noted that, just as the previous industrial revolutions were accompanied by significant changes in the structure of labor, the current trends in automation and the introduction of robotics are associated not only with the disappearance, but also with the emergence of new jobs and areas of employment of labor resources. With the appropriate formulation of the question, effective and demanded measures for professional retraining and social support of population groups at risk.

The authors found that robotics as an interdisciplinary direction of science and technology is a large technological system. It has been established that the global robotics market has a composite character and includes industrial, professional service and personal service segments. The factors of the development of the global robotics market, especially the segment of industrial robotics, were analyzed and described. It has been established that the demand for industrial robots depends on the state of the world economy and the dynamics of development of enterprises in the automotive and electrical / electronic industries, which are key consumers of robotics.

A tendency towards deepening geographic specialization in the global robotics market is revealed. In the group of leading countries-manufacturers of robots, the author includes China, the USA, Japan, Germany, the Republic of Korea, Singapore, Switzerland, etc. It has been established that in the segment of industrial robotics the leaders are Japan, Germany, and Switzerland, and in the segment of professional service robotics - USA. The authors found that at the present stage there is an increase in demand for industrial manipulators, collaborative robots, robotic solutions in the field of warehouse logistics and systems for inventorying goods in stores, as well as medical robotic devices.

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8. Competing interests

The authors declare that they have no competing interests.

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