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THE SMART MANUFACTURING: IMPERATIVES AND TRENDS

ABSTRACT

The aim of the article is to learn the processes of smart economy, in particular such aspects as a development of a smart manufacturing and a formation of a smart market. With the help of graphic visualization methods, the trends of digitalization, the penetration of the latest ICT technologies into global production and logistics processes were characterized. The methods of system analysis and generalization, made it possible to formulate the key imperatives, which characterize the formation of smart manufacturing: comprehensive digitalization, the spread of artificial intelligence, the industrial robotics and the industrial Internet of Things, the formation of global supply chains and a new type of production networks. The important features of Industry 5.0 are: a trend of green economy and ensuring the stability and the resilience of the system. The extrapolation of the obtained conclusions to Ukrainian economy made it possible to determine the key imperatives for its recovery in a smart context: global digitalization, a course towards a green economy (the priorities of which should be present in all goals and directions of post-war recovery and reform), formation of the foundations of resilience in the face of numerous internal and external challenges and threats.

Keywords: economic resilience, green economy, artificial intelligence, Industrial Internet of things, industrial robotics, industry 5.0, smart demand, smart market

JEL Classification: F21; O31; O33; O50

INTRODUCTION

Most often, the smart economy is perceived in the context of smart cities, in which the use of the latest technologies allows creating comfortable living conditions for people. At the same time, smart economy is a complex large-scale phenomenon that reflects transformations in all spheres of the economic life of society and, first of all, the very basis of the economy - production and the entire system of production activities.

Influenced by the latest technological expansion (Artificial Intelligence, Internet of Things (IoT) and Industrial Internet of Things, Cyber-Physical Systems (CPS), Big Data, Cloud Computing, Additive Manufacturing, Augmented Reality, etc.) the technological basis of modern production is changing, new business models are being formed, which are based on integrated intelligent control systems. These new business models focus on individual consumer needs, affordable and transparent pricing, and free shipping. The flexibility and adaptability of production is ensured by the combination of all parts of the production and logistics processes into a single system of functioning, controlled by innovative technologies in real time mode. All these processes, combining the virtual and real world, create a global space that has its own technological features and laws of development.

It is important to note that human society is able to give this space a reasonable vector of development. In the process of implementing the goals of sustainable inclusive development, climate conservation, human-centrism, etc. a reasonable, intellectual (smart) character of modern production and the economy in general is being formed.

LITERATURE REVIEW

The problems of smart economy are very relevant in the world scientific literature. The vast majority of research in this direction is devoted to various aspects of the development and functioning of smart cities, in particular: M. Angelidou (Angelidou, 2016); L. Galperina; V. Mazurenko (Galperina, 2016); A. Caragliua (Caragliua, 2012); R. Giffinger (Giffinger, 2007); V. Kumar (Kumar, 2012); P. Lombardi, S. Giordano, H. Farouh & W. Yousef (Lombardi, 2012); R. Novotny (Novotny, 2014); A. Pozdniakova (Pozdniakova, 2017); S.M. Sureshchandra, J.J. Bhavsar & J.R. Pitroda (Sureshchandra, 2016) and others.

No less relevant is the issue of the formation of Industry 4.0, various aspects of which are developed in the works of many scientists: S. Bag (Bag, 2021), G. Büchi (Büchi, 2020), I. Castelo-Branco (Castelo-Branco, 2019), T. Čater (Čater, 2021), G. Culot (Culot, 2020), M.R. Ejaz (Ejaz, 2023), M. Ghobakhloo (Ghobakhloo, 2019), A. Gorkhali (Gorkhali, 2022), S. Kumar (Kumar, 2022), A. Kusiak (Kusiak, 2018), J. Łabędzka (Łabędzka, 2021), H. Lasi (Lasi, 2014), Y. Lu (Lu, 2017), M. Mariani (Mariani, 2019), S. Mittal (Mittal, 2019), J.M. Müller (Müller, 2018), A. Rojko (Rojko, 2017), M. Sarbu (Sarbu, 2022), A. Stocker (Stocker, 2021), F.E. Touriki (Touriki, 2021), L.D. Xu (Xu, 2020), P. Zheng (Zheng, 2018) and many others.

The appearance of the concept of Industry 5.0 actualizes the need to study this phenomenon, identify its essential features, development factors and dynamics in different countries of the world. There are still quite a few studies of Industry 5.0: F. Aslam (Aslam, 2020), D. Battini (Battini, 2022), M. Javaid (Javaid, 2020), G.F. Frederico (Frederico, 2021), K. Fukuda (Fukuda, 2022), P.K.R. Maddikunta (Maddikunta, 2022), S. Nahavandi (Nahavandi, 2019), G. Shaji (Shaji, 2020), X. Xu (Xu, 2021), F. Yavari (Yavari, 2021).

Thus, in the Scopus database, a search for "Industry 5.0" returns only 51 scientific works, while a search for "Industry 4.0" - 1,519 works. Even the concept of Industry 6.0 is already found: S. Chourasia (Chourasia, 2022). This confirms the necessity and relevance of research in this direction.

AIMS AND OBJECTIVES

The purpose of the article is to learn the processes of smart economy, in particular such aspects as a development of a smart manufacturing and a formation of a smart market.

METHODS

With the help of graphic visualization methods, the trends of digitalization, the penetration of the latest ICT technologies into global production and logistics processes were characterized. The methods of system analysis and generalization, made it possible to formulate the key imperatives, which characterize the formation of smart manufacturing: comprehensive digitalization, the spread of artificial intelligence, the industrial robotics and the industrial Internet of Things, the formation of global supply chains and a new type of production networks.

RESULTS

The general logic of the progress of smart manufacturing in the modern environment lies in the development of the use of digital technologies in individual production processes (product modelling, transition to electronic document management, storage of information on distributed resources ("cloud" technologies), etc.) to the creation of integrated management systems for all stages and links in production and logistics processes (massive use of intelligent sensors in equipment and production lines), the introduction of robotic technologies, the use of unmanned technologies in transport systems, the sale of products via the Internet). Smart manufacturing is based on a combination of physical and virtual environments (CPS), which allows the entire manufacturing industry to focus on creating superior products, increasing productivity, improving energy efficiency and maintaining safety.

Thus, the US National Institute of Standards and Technology (NIST) defines the term Smart Manufacturing as "fully integrated corporate manufacturing systems that can respond in real time to changing production conditions, supply chain requirements and meet customer needs". In this definition, the main thing is: "in real time mode", that is, as quickly as possible, the named goals are achieved through the intensive and comprehensive use of information technologies and cyber-physical systems at all stages of products manufacturing and delivery. (What is Smart...). Dan Green, director of the United Advanced Manufacturing Region (JAMR) defined Smart Manufacturing as a convergence of operational technology

(OT) and information technology (IT) working together in real time mode (So What...). The Smart Manufacturing Leadership Coalition (SMLC) defines smart manufacturing as follows: "it is the ability to solve existing and future problems with a help of an open infrastructure that allows solutions to be implemented at the speed of business, while creating an advantage" (What is Smart...).

Deloitte defines, "A smart factory is a flexible system that can independently optimize performance across a wider network, independently adapt to new conditions and learn from new conditions in real or near real time, and at the same time to autonomously run entire manufacturing processes." (The Smart Factory, 2017) There are five key functions of smart manufacturing: connectivity, optimization, transparency, proactivity and flexibility. Deloitte has estimated that the US manufacturing industry could face a shortage of 2 million workers over the next decade. Many companies are investing in smart factory capabilities to mitigate the risk associated with this possibly pervasive labour shortage. However, such a move could create a new set of talent-related implications, as automated assets typically require highly skilled personnel to operate and maintain. The choice of the location of production facilities requires taking into account such factors.

Thus, the first distinguishing feature of smart production is unlimited access to data. Secondly, these are technologies that allow you to contextualize and use this data for production or logistics purposes. Modern programs allow you to help track costs, the location of people and funds, find optimal solutions for the use of resources, etc. In smart manufacturing, complex issues of security, intellectual property, and the combination of resources for production are solved. It integrates data and information from many open source and procurement programs and products that can be created to generate new solutions. Smart manufacturing creates an open environment where decisions are made based on a large body of data and facts. Moreover, this data can be obtained by the relevant decision makers, whenever they are needed, where they are needed, and in exactly the form that is most useful for the case.

Smart manufacturing opens up new areas for innovation that aims the entire manufacturing industry to create superior products, increase productivity, improve energy efficiency and safety. Smart manufacturing can be implemented locally (on a single production line), throughout the enterprise, or throughout the supply chain. And it can integrate and synchronize all these parts. Smart Manufacturing provides small and medium sized manufacturers with access to new and growing forms of business intelligence. There is evidence that smart manufacturing also creates opportunities to increase employment by 2-4 times. With SM, new jobs are created based on new technologies, creating direct production and non-production positions. The creation of such plants will allow the United States to have competitive production facilities abroad, which are already being created with embedded technologies. Smart Manufacturing (What is Smart...).

As for the terminology of the transformation of production itself, the term Industry 4.0, which arose and developed in German science and practice, is better known in the scientific literature and practice. The concept of Industry 4.0 was first introduced to the German government in 2011. A team of researchers (The Industry 4.0 Working Group) was formed to study the state of modern manufacturing and Germany's place in it. In 2012, the Working Group compiled a list of recommendations for the government, and in 2013 it was presented at the Hannover Fair. These recommendations outlined the research and development required for a successful transition to Industry 4.0 (Recommendations..., 2013). In 2016, Industry 4.0 became the main topic of the World Economic Forum.

The technological revolution is described by scientists as going through four stages. Industry 1.0 - the end of the 18th century, the Industrial Revolution was the result of the introduction of mechanical production facilities operating on water and steam (1784 - the appearance of a mechanical loom). Industry 2.0 - beginning of the 20th century, the revolution occurs with the introduction of electrical mass production based on the division of labour (1870 - the first production line in the slaughterhouses of Cincinnati). Industry 3.0 - the beginning of the 70s of the twentieth century, associated with the use of electronics and IT for further automation of production (1969 г. – First programmable logic controller (PLC), Modicon 084). Industry 4.0 is unfolding in our time and is based on Cyber-Physical Systems (Recommendations..., 2013).

The key impetus for the advent of Industry 4.0 was the Internet of Things, which allows the creation of networks that connect the entire production process and turn factories into a smart environment. Cyber-physical manufacturing systems include intelligent machines, warehouse systems and manufacturing facilities digitally designed and end-to-end ICT-based integration, from inbound logistics to production, marketing, outgoing logistics and service. This not only allows for more flexible production customization, but also creates much more differentiated management and control opportunities. Such systems can accumulate all information, exchange it autonomously, launch all processes and independently control each other. This is fundamentally changing all manufacturing processes, from product development, the use of resources in production, and building the entire supply chain and value creation. It also involves closer collaboration between business partners (such as suppliers and customers) and between employees, providing new opportunities for mutual benefit (Recommendations..., 2013).

At the same time, modern technological progress continues to develop rapidly and, at the same time, acquires new features in response to the challenges of the 20s of the XXI century. Currently, the concept of Industry 5.0 is emerging, which should overcome the limitations of the previous paradigm and pose new challenges. Since 2020, the European Commission has been discussing the limitations of Industry 4.0 and raising the question of Industry 5.0. The policy brief "Industry 5.0: A Transformative Vision for Europe" indicates that Industry 4.0 was more about the transformational aspects of the impact of modern digital technologies and changing of business models. Industry of models, climate change, pandemic and other crises lead to instability and cause significant social tensions. The transition to 4.0 also led to an increase in social inequality between different countries, since in the modern digital economy, technologically advanced states and corporations immediately took primacy and even a monopoly on certain segments. Industry 4.0 lacks several basic dimensions that are essential for a more sustainable and equal society:

- Features of the regeneration of industries, which should lead to a full circular economy, and ensure full consideration of environmental changes, as well as climatic and social changes;
- A deeply organic social dimension that would focus on workers, their state and develop approaches not to replace them with technology, but rather to complement them;
- Mandatory consideration of environmental impact, which should lead to changes in the use of fossil sources, reduced carbon emissions and better energy efficiency.
- Thus, the European Commission concludes that "Industry 4.0 is incompatible with the goals of a climate-neutral economy and the goals until 2030. Unlike Industry 4.0, Industry 5.0 is about two other transformations:
- Full connectivity with the Green Deal, leading to better permanence and a circular economy (dual digital and green transition).
- Improving the reliability, resilience of value added chains (VAC) and ecosystems to new shocks, whatever their sources (pandemics, natural disasters, geopolitical changes, regional wars, etc.)» (Industry 5.0: A Transformative Vision for Europe).

Thus, the concept of Industry 5.0 implies two key provisions. First, the course towards a green and digital economy. And although this priority has already been voiced before, in a new sense it will mean greater attention to the needs of man and nature. It is believed that in Industry 4.0, process automation has been given priority and human intervention has been minimized. In other words, humans have been moved to other aspects of the production process that machines cannot do, and robots have been given more space throughout the entire production process. In Industry 5.0, the goal is to change this situation and achieve a greater balance between man and machine in the production process.

The second important point is related to the need to ensure greater sustainability of the economy and the transition to such economic ecosystems that are more resilient to future shocks and stresses, namely, ensuring the resilience and reliability of ecosystems to external challenges. Europe's mission must now be to ensure that European industrial development is sustainable, while facilitating and accelerating the transition to an era of sustainable prosperity for all. A pan-European industrial strategy focused on the constitutive elements of Industry 5.0 should unlock Europe's industrial potential and promote stable, sustainable, regenerative and circular economic behaviour rather than short-term overproduction and consumption patterns driven by the current growth paradigm (Industry 5.0: bachennja...).

Industry must be regenerative and restorative in design and action, recovering resources used in the past, interconnected with the natural world, adaptive to changes and based on a key responsibility for social justice. Industry 5.0 must provide the direction needed to spur innovation at scale that creates new forms of economic and social value that effectively balance people, planet and prosperity. This transformation can only be achieved if it is accepted at all levels of government; it should be promoted and used to harmonize key policies in the international arena (Industry 5.0: bachennja...).

Industry 5.0 features also include:

- customization: Industry 5.0 creates products with a higher degree of personalization, better tailored to the individual needs of customers;
- distribution of Cobot: not robots, but cobots that help, collaborate, go alongside human ingenuity and creativity, producing personalized products;
- increasing the human capability: instead of relegating humans to a secondary position, Industry 5.0 plans to leave all repetitive mechanical tasks that require effort and are dangerous for humans to AI and robots. Thus, a person can have more time for tasks that only he can complete;
- speed and quality: thanks to new technologies, new production lines will run faster. In addition, products will be of higher quality due to more human intervention;

- respect for the environment: a transition to renewable energy sources and production chains with less need for resources, reducing emissions, waste and creating more sustainable products (Industry 5.0: Scho ...).

Thus, the latest technologies not only speed up all production processes and increase production efficiency, but also create opportunities for fundamentally new production techniques and methods, qualitatively new forms and quality control systems. It is clear that under these conditions both the production process and the enterprise where production is carried out are transformed, becoming intellectually saturated.

Transformations of the global market are reflected at every stage of the business activities of companies. The expansion of smart technologies goes from the stage of reasonable supply and production to the moment of reasonable consumption (Figure1):

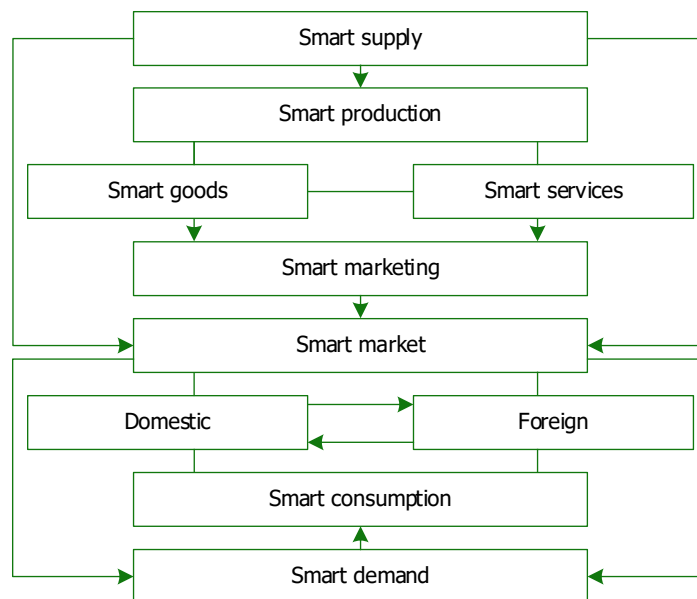


Figure 1. General outlines of structural composition.

The emergence of smart production transforms all other areas of the economy: the market and market relations, the characteristics and features of the actors of such relationships [Smart-marketing...], demand, consumption, marketing, etc. Consumer requirements set limits on the production of goods and form new realities for the promotion of goods on the market. The market is subject to new laws and realities; the concept of smart marketing, smart consumption and smart market as such is being formed. The international market and logistics systems, developing under the influence of these technologies, are generally undergoing significant changes. A smart marketing system is being formed, integrated with smart tools for logistics activities, in a single communication system of the chains of participants (both production and supply chains) to increase their efficiency, form a sustainable architecture of the logistics information system. Under such conditions, new rules of the game are being formed in the markets, which are closely interdependent with global processes. New technologies are changing business processes, in turn forming global trends that put forward a new bar of requirements for business activities. New quality, new technical solutions create preferences for the consumer, increasing the competitiveness of the company and the effectiveness of its decisions.

Reasonable approaches in marketing activities are implemented through specific goals and objectives that are set for the company. Marketing activities are aimed at analyzing market activity, evaluating the effectiveness of communications, a combination of data sources, which allows you to create a "market on the phone", which involves the use of mobile applications. The digitalization of the market helps in the formation of analytical pools, because it can provide an easy analysis of the number of purchases, travel routes, etc. This in turn can be used to plan future marketing activities. It should be noted that any production in the modern composition of the world market cannot be isolated; it is always a structural element of global production and logistics chains and is influenced by global trends.

According to McKinsey's research, the overall structure of global flows of goods, capital and other resources is undergoing significant changes, as the share of knowledge and know-how is steadily growing:

Table 1. Global flows growth dynamics, %. (Source: *Global flows*, 2022...)

	2010-2019	2019-2021
Resources	0.4	5.8
Manufactured goods	2.7	6.1
Services	-1.8	4.6
Intangibles	5.8	7.4

The study also draws the following conclusions:

1. In the past decade, new flows of knowledge and know-how have come to the fore decisively, in contrast to manufactured goods, resources and capital, the main drivers of global interconnectedness 20 years before the global financial crisis. Flows of Data, services, intellectual property (IP) and international students are currently growing the fastest. Between 2010 and 2019, cross-border data flows increased at a staggering 45 percent annual rate, rising from about 45 to 1,500 terabits per second.
2. Over the same period, services, IP, and international student flows grew at a slower rate, but still at about 5-6 percent per year, about twice the rate of growth in merchandise trade. The number of highly skilled migrants has grown noticeably faster than total migration.
3. Typically, trade flows have tended to become more knowledge-intensive. Between 2010 and 2019, services became the fastest growing class and resources grew the slowest, reversing the order of relative growth observed between 1995 and 2008.
4. In the scope of services, the fastest growing flows are knowledge-intensive services, including professional services, government services, IT services and telecommunications. In industrial goods, most value chains have become more intangible (Global flows...).

Such a change in the dynamics of global flows is continued in general changes in the structure of the market, changes in supply and demand, and so on. According to experts, the growth potential of the market for high-tech products (within the so-called "factories of the future") is extremely huge. In general, the market volume is gradually increasing and the market of PLM-systems (Product Lifecycle Management), additive technologies, hardware and numerical software, machine tools, etc. will reach 740 billion dollars. by 2035.

The volume of intelligent production will increase to USD 1.35 trillion by 2035. By the same year, the Virtual Factory segment is projected to grow to USD 1.5 trillion (Smart Factory). This market is being formed both by building new enterprises based on Smart Factory and even Virtual Factory, and by transferring existing enterprises to the basis of technologization through the transition to new principles of production planning, supply, pre-sales and after-sales services. (Smart Factory).

Accordingly, companies must take into account the needs of the market, which will be characterized by a significant increase in the costs of the latest technologies. According to Gartner forecasts, global IT spending will increase by more than 5%, to USD 4.6 trillion in 2023 in compare with 0.8% in 2022 and 10.2% in 2021 (Enterprises...). According to the company's research, a global forecast for IT costs has been formed (Table 2.):

Table 2. Global forecast for IT costs, USD mln. (Source: *Enterprises...*)

	Costs 2021	Growth 2021, %	Costs2022	Growth 2022, %	Costs 2023	Growth 2023, %
Data center systems	185.506	6.1	209.190	10.4	216.262	3.4
Software	732.030	14.8	790.385	8.0	879.625	11.3
Devices	807.580	15.8	739.982	-8.4	735.394	-0.6
IT Services	1.207.966	12.8	1.258.150	4.2	1.357.914	7.9
Communications Services	1.459.483	3.8	1.435.401	-1.7	1.469.220	2.4
Overall IT	4.396.565	10.2	4.433.108	0.8	4.658.416	5.1

According to research and forecast, spending on devices will fall by 0.6% with a total of USD 735.394 billion in 2023 from USD 739.982 billion (-8.4%) in 2022. The IT services sector, on the contrary, shows an increase of 7.9% to USD 1357.914 billion in 2023. Communications services and costs show an increase of 2.4% to USD 1469.220 billion in 2023 out of USD 1435.401 billion (-1.7%) in 2022. Thus, in general, the market shows an upward trend, given the key trends in technologization, because even business in times of crisis and recession does not reduce the costs of the IT sector, on the contrary, increasing costs for digital business initiatives. And while a significant number of consumers may delay purchasing high-tech products in times of crisis, technology development must be constant to offer consumers ever better products. Thus, in 2022, there was an 8.4% decrease in device costs, but this is a carry-over demand for 2023, which is potentially laid down in the future market structure.

Such trends determine the change in the general fundamentals of the market, because the possibilities of technologization form a higher level of efficiency both in the field of the cost system and in the formation of a profitable component, providing a new design, large-scale production, risk reduction, reduction of production waste and the possibility of their processing, etc. (Tassel, 2019). There is a constant digitalization of the population of countries today more than 3 billion people use mobile telephony and mobile Internet services, demonstrating an annual growth of more than 10%. The ITU estimates that approximately 5.3 billion people – or 66 percent of the world's population – use the Internet in 2022. This is 24% more than in 2019. (Statistics...). The number of mobile users in 2022 exceeded the total population of the world (108 per 100 people) (Measuring, 2022).

Technologies of voice assistants, the Internet of things (IoT) are being actively introduced, which generally destroys the classical sales system, changing the end consumer, decision-making capabilities, etc. As a result of this, the e-commerce segment is growing, which accordingly requires the formation of new business models of companies that can meet new requirements and consumer needs, even forming new markets that new players and new technologies are entering. This, accordingly, requires the transformation of the business, requiring the technologization of each stage of production, increasing the level of innovation and the formation of a sustainable and stable production system aimed at meeting the needs of consumers.

Consumers, forming demand, put forward requirements for greater flexibility of companies, an increase in the options for supplying products, customization of the actual products themselves that meet the requirements of the consumer, and not the capabilities of the company. In fact, a new ecosystem is being formed, aimed at meeting the needs of consumers, generating demand and providing them. Such a system should be adaptive, capable of self-learning and self-organization, self-correction of shortcomings and weaknesses, ready for changes and new consumer needs. Reasonable demand creates new requirements for business, providing a certain framework for time and opportunities, for example, product delivery, requiring the use of artificial intelligence technologies, digital platforms for the operation of production, distribution and storage structures. Meeting the needs of consumers requires the formation of a multi-channel customized system, which in turn implies the creation of a new technological platform.

Robotization of technical tasks allows you to free up human resources to perform more complex tasks that require an understanding of human nature and require understanding of human behaviour. According to the World Economic Forum, an example of such an intelligent platform, guided by the principles of technologization and greening, is the P&G Rakona Fabric and Home Care production site in the Czech Republic, which demonstrates the possibilities of introducing 4IR technologies into the activities of companies. This platform demonstrates the ability to address both overstocking and inventory management and customer satisfaction with maximum efficiency.

The company's approach is defined as continuous self-improvement based on analytical modelling and simulation, which can be seen as an option to reduce stress in supply chains and increase flexibility in solving certain problems. Using the Rakona platform reduced costs by 35% over three years of operation, increased inventory efficiency by 7% and reduced the number of returns in the chains, which improved the efficiency of the warehouse system and supply chains as a whole (Tassel, 2019).

In general, such activities are typical for most modern businesses, which aim to maintain and increase competitiveness. According to IDC experts, in general, the market for digital technologies, mixed reality technologies in 2021 amounted to 82 billion dollars USA, where augmented reality (AR/VR) technologies reach USD 56 billion dollars USA [PC Monitor, 2021]. This market segment has been growing dynamically in recent years. We can observe a slight decline in the market volume only during the onset of the pandemic, which led to a decrease in business activity in general. However, now there is not only a recovery of the market, but also its intensification. Thus, the growth of the personal computer market has already reached the pre-pandemic level and continues to develop quite dynamically.

In 2022, the crisis led to a reduction in the market for augmented and virtual reality headsets by 12.8%, to 9.7 million units, but growth is expected in 2023 by 31.5% in just a year. In general, according to the data of IDC Worldwide Quarterly Augmented and Virtual Reality Headset Tracker the deliveries will grow by 31,5% per year, and accordingly, during the next period the growth for more than 30% is expected, reaching 35,1 million of units, supplied in 2026 (Tracker). The market leader in AR/VR headsets during the first three quarters of 2022 was Meta, which was made possible by the low price of Quest 2, which generated 84.6% of the market. At the second place was Pico by ByteDance with a 7.4% share over the same period. Rounding out the top 5 are DPVR (1.8%), HTC (1.1%) and iQIYI (0.9%), however, each of these companies will face challenges next year as Sony releases the next generation of headsets, and also on Apple [IDC Tracker] will enter the market. Overall, this market is showing extraordinary growth. According to forecasts, the market of augmented reality will grow by 2305%, and the market of virtual reality - by 288% (Table 3).

Table 3. Worldwide AR/VR Headsets Forecast, 2022 Q4. (Source: AR & VR Headsets, 2022)

Product Category Group	2022	2023	2024	2025	2026	2027
Augmented Reality	278.282	468.251	860.979	1.631.341	3.719.640	6.414.072
Virtual Reality	8.548.436	9.592.643	13.267.406	17.203.888	21.042.638	24.648.655

According to the company's experts, the market for the industrial use of such gadgets and headsets will increase significantly, even outpacing consumer use. In industry, this can be used as an element of learning, using end-to-end capabilities. [Preparing]. All this makes it necessary to determine the level of digitization of the business as a whole, forming new trends in the digital transformation of the business. According to a new update to the International Data Corporation (IDC), global spending on the digital transformation (DX) of business practices, products, and organizations is reach USD 1.8 trillion in 2022, an increase of 17.6% over 2021. DX spending will sustain this pace of growth over the 2021-2025 forecast period with a five-year compound annual growth rate (CAGR) of 16.6% (Worldwide).

The dynamic growth in the consumption of new types of products becomes the basis for the formation of new markets. Accordingly, companies see digital transformation as a necessary condition for their competitiveness. This requires scaling up the application of the latest technologies in the processes of production, construction, design, research, methods of working with customers, etc.

As you can see, practically all business processes that work to help form a new level offer to meet the demand of a new format and quality become key objects of attention. The penetration of smart technologies into all areas of economic activity is reflected in the results of business activities of companies, the levels of sales of high-tech products, which is explained by high demand from both the end consumer and new trends in the development of the high-tech B2B sector, which forms the market for intermediate goods, equipment, systems, service, etc.

The formation of national strategies for smart entrepreneurship or the entire socio-economic development should, first of all, take into account the trends in the formation of global models of the future. Modernization and deep transformation of production requires a strategic vision of the development of the economy as a whole. The recovery of the Ukrainian economy requires a systemic reconstruction based on the formation of a smart ecosystem and the achievements of Industry 4.0 and Industry 5.0. This, in turn, requires the use of the latest achievements of technological development to form the basis for further technologization and smartization of economic and entrepreneurial activity. It is worth noting that the nationwide Strategy for the Development of Industry of Ukraine needs to be updated, which should include and take into account the development of smart industry as part of it. The pre-war strategy took into account the needs of decarbonization, increasing the energy efficiency of industry, gradual technologization and updating the regulatory framework. 2022 was catastrophic for the Ukrainian economy: GDP as a whole decreased by 29.1%, and individual sectors even more (construction - by 67.6%, professional, scientific and technical activities - by 46.2%, transport - by 44.3 % %, processing industry - by 43.1% Export significantly decreased - by 42.4%, and import - by 18.5% (Figure 2).

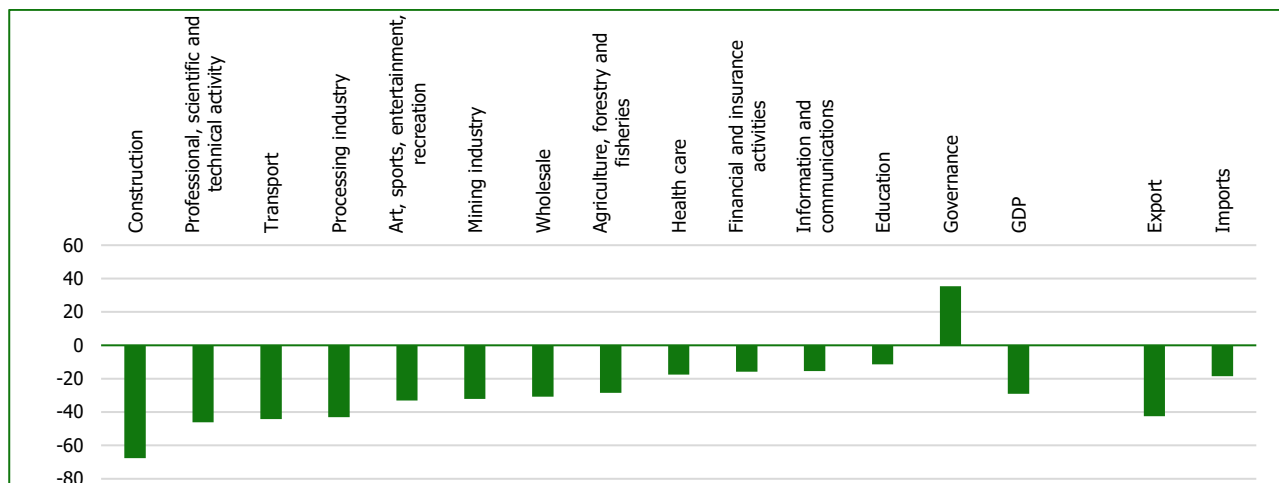


Figure 2. Changes in the GDP of Ukraine in 2022. (Source: *The change, 2022*)

It is clear that in such conditions the task of restoring the economy and achieving the pre-war level of production becomes a top priority. At the same time, such a significant destruction of the Ukrainian economy actualizes the need for a systemic restructuring of economic activity on fundamentally new principles. In view of the fact that the key foundations for the formation of smart production are the development of technologies and the formation of smart demand, it should be noted that in a crisis, demand has a much lesser impact. This is due to the lack of a certain motivation among the population or the presence of financial, temporal or physical constraints. That is why government regulation and stimulation of investments in smart business or smart technologies should play a key role in the post-war recovery. According to scientists (Smart-promislovist..., 2019), the key areas for the development of the smart economy in Ukraine are: Industrial Robotization; Artificial Intelligence; Industrial Internet of Things.

These key areas should be implemented in priority sectors of economic activity, which make up a significant part of Ukraine's GDP and exports. The priorities include metallurgy, which, although it suffered significantly as a result of hostilities, however, needs to be restored on a fundamentally new basis, which in turn allows the implementation of the best examples of technologization. Such trends are caused both by the actual need to restructure the industry, and by the possibility of its revival at a different technological level.

The formation of Industry 5.0 creates the basis for a new type of market relations, which involves the formation of supply chains and production networks of a new type. Comprehensive computerization, digitalization, penetration of new technologies, artificial intelligence are global development trends that form not just prerequisites for market development, but act as certain super-global imperatives for the formation of the entire system of relationships, changes in the structure and quality of the business environment, supply chain management, etc. In addition, the formation of Industry 5.0 should also mean a clear course towards a green economy, the priorities of which should be present in all goals and directions of post-war reconstruction and reform.

An equally important task is to ensure the resilience of the Ukrainian economy, that is, the creation of principles for the speedy recovery, returning to the pre-crisis state. For modern Ukraine, this task acquires special relevance. The dynamics of overcoming such a decline in production, as noted in Figure 5, depends on many factors, including external ones. Ensuring the resilience and stability of the system is a separate complex problem that requires further in-depth research.

The formation of a reasonable nature of production in Ukraine is a non-alternative way. At the same time, this process is taking place in conditions of great challenges and threats. The external environment is characterized by high competition and the emergence of new competitors, given that Ukrainian companies need to create unique advantages and increase the level of efficiency of their own activities. Internal difficulties are related to the fact that this should take place during the war, which requires companies and the government to make titanic efforts to keep the Ukrainian economy. One of the tools is the development of smart technologies for Ukrainian entrepreneurship, which contributes to increasing labour productivity and faster recovery of companies. Large industrial complexes have suffered significantly from military aggression and have been forced to stop their own investments in technology development. Even in the pre-war period, large metallurgical complexes, characterized by certain inertia of activity, began their restructuring on smart rails. The leaders of the smart market have also become pharmaceutical, agro-food, chemical enterprises and, of course, the IT industry. It seems that these areas should become flagships for the development of a smart economy in post-war Ukraine. Support for these sectors in this direction will allow creating such impulses, growth drivers for the entire economy on a new basis.

DISCUSSION

Such general trends in the development of production require further in-depth research. New technologies certainly bring great progress in production systems, but also significant negative consequences. First of all, it is connected with significant changes in the labor market. After all, the spread of artificial intelligence technologies, robots, augmented reality, etc. will lead to the disappearance of many professions and a reduction in demand for others. The result of such processes will be a simultaneous increase in unemployment and a shortage of specialists in other specialties. The impact of the latest technologies on the industry structure of production is also the same. On the one hand, the rapid development of some sectors of production will gradually reduce the share of other industries.

All these processes require further serious analytical studies and forecasts. In our opinion, the advantages of the latest technologies are unquestionable, as they mark a new paradigm of production. That is why we consider the research of new features and imperatives of this paradigm to be an urgent problem. However, it is no less important to investigate and predict all the negative consequences of the spread of the latest technologies, which may manifest themselves in economic and social activities, influence the psychological features of personality development, etc. These developments must necessarily translate into targeted policies to prevent and manage these disparities and challenges, present and future. And if we are talking about building Industry 5.0 in Ukraine, the imperatives of green economy and resilience are key.

CONCLUSIONS

The formation of a smart economy is a complex process of penetration of smart technologies into all spheres and aspects of economic activity. This is a complex large-scale phenomenon that reflects transformations in all spheres of the economic life of society and, first of all, the very basis of the economy - production and the entire system of production activities. Modern production is being transformed under the influence of the spread of artificial intelligence technologies, industrial robotics and the industrial Internet of things, etc. Based on integrated intelligent control systems and the use of cyber-physical systems, new business models are being formed, and the transformation of production inevitably changes the entire system of supply and demand. In general, this leads to the formation of a smart market, global chains and production networks of a new type.

The emergence of smart production is accompanied by the emergence of the concept of Industry 5.0, the key features of which are: a green and digital economy and ensuring the sustainability and resilience of the entire ecosystem. Unlike the concept of Industry 4.0, the modern paradigm implies greater attention to man and the development of nature, new challenges of climate change, pandemic threats, and social problems. Transformations are becoming important in the direction of improving the resilience of value chains and ecosystems in general to any shocks and possible threats.

For modern Ukraine, the formation of a reasonable nature of production is an important and necessary direction of post-war economic recovery. Key imperatives for restoring the Ukrainian economy on smart principles include: comprehensive digitalization, a course towards a green economy (the priorities of which should be present in all goals and directions of post-war recovery and reform), the formation of principles of resilience in the face of numerous internal and external challenges and threats.

ADDITIONAL INFORMATION

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СМАРТВИРОБНИЦТВО: ІМПЕРАТИВИ Й ТРЕНДИ

Метою роботи є дослідження процесів смартекономіки, зокрема таких аспектів як розвиток смартвиробництва та формування смартринку. За допомогою методів графічної візуалізації охарактеризовано тенденції диджиталізації, проникнення новітніх ІКТ-технологій у світові виробничі та логістичні процеси. Методи системного аналізу та узагальнення дозволили сформулювати ключові імперативи, що характеризують становлення смартвиробництва: всеохоплююча диджиталізація; поширення штучного інтелекту, промислової роботизації та промислового інтернету речей; формування глобальних ланцюгів постачання й виробничих мереж нового типу. Важливими рисами Індустрії 5.0 також стають: курс на зелену економіку та забезпечення стійкості, резильєнтності системи. Екстраполяція отриманих висновків на ситуацію в українській економіці дозволила визначити ключові імперативи для її відновлення на смартзасадах: всеохоплююча диджиталізація, курс на зелену економіку (пріоритети якої мають бути присутні в усіх цілях та напрямках післявоєнного відновлення й реформування), формування засад резильєнтності в умовах численних внутрішніх та зовнішніх викликів і загроз.

Ключові слова: економічна стійкість, зелена економіка, штучний інтелект, промисловий інтернет речей, промислова робототехніка, Індустрія 5.0, розумний попит, розумний ринок

JEL Класифікація: F21; O31; O33; O50