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Original Scientific Paper

INDUSTRY 4.0 DEVELOPMENT CONDITIONS IN THE REPUBLIC OF SERBIA

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Abstract. *The fourth industrial revolution is about the development of Industry 4.0, the changing of the production paradigm and economic digitalization. The research subject are the development conditions of Industry 4.0 in the Republic of Serbia. The main research objective is to point out the importance of the efficient development of Industry 4.0 and the implementation of structural changes through the process of digitalization and application of technological innovation in the manufacturing industry. The method of analysis is used to identify the concepts of Industry 4.0 and the new industrial paradigm. The comparative method is used to compare technological criteria and changes. The development conditions of Industry 4.0 are analyzed indirectly through technological criteria and innovation, i.e. data obtained from survey on innovation, individual innovation and technology indicators and composite indicators. Industry 4.0 is an important factor in technological and structural change, economic growth and competitiveness. The research results show that the Republic of Serbia lacks incentives for the development of Industry 4.0. The research results are useful to industrial policy makers as they point to some of the key factors and directions of change to create the conditions for the development of Industry 4.0, the manufacturing industry and the digital transformation of the economy.*

Key words: *Industry 4.0, manufacturing industry, digitalization, innovation, technological change*

JEL Classification: O14, O30, O33

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1. INTRODUCTION

The fourth industrial revolution concerns the development of Industry 4.0 (Industry 4.0 – I4.0) or networked "smart" industries and factories of the future, which is related to the concept of smart (intelligent) production. The fourth industrial revolution and "smart factories" are creating a world that enables virtual and physical production systems to engage in global and flexible collaboration. This allows for complete customization of products and creation of new business models (Schwab, 2017).

The concept of I4.0 is thought to be the main driver of the fourth industrial revolution (Stankovic, et al., 2017), and is based on knowledge and a range of new trends and technologies, notably artificial intelligence, new generations of digital technology and infrastructure, artificial intelligence, machine learning, robotics, the Internet, nano technology, genetic modification, new types and modes of energy and information storage, quantum computing, genetics and biotechnology. The fourth industrial revolution relies on digital revolution technology, which focuses on artificial intelligence, nano technology and mobile devices. "These innovation platforms provide limitless opportunities for knowledge creation and transfer. They rapidly multiply innovations, which affects development of a society, its structure and dynamics, its value system, as well as people's daily lives" (Bazić, 2017).

The start of the fourth industrial revolution links to the 2011 Hanover Industrial Technology Fair in Germany. It has become a driving force of exit from recession, re-industrialization, competitiveness growth and recovery of EU economies.

In the fourth industrial revolution, new technology and innovation are introduced much faster, and in some parts of the world revolutions are not over yet. The fourth industrial revolution is also unique because of the increasing integration of different disciplines and discoveries (Schwab, 2017). Certainly the most significant change and challenges lie in new and efficient technologies, but also a profound impact on the industry dynamics and structure, the need for new industrial policy, digital globalization, and the changing role of training and education (Vujović, 2019).

Although focusing on the manufacturing industry, I4.0 is broader in scope than the fourth industrial revolution, and it is widely believed that I4.0 is the driver and structural component of the revolution. The fourth industrial revolution relies on digital revolution, which means new ways for technology to become a building block of the economy, and is marked by the emergence of technological innovation in numerous domains of human society. Compared to the previous ones, it develops at an exponential pace, and the breadth and depth of its changes influence the transformation of production, management and governance (WEF, 2016).

I4.0 is a new industrial paradigm that embraces the application of modern technologies in industrial production (Pereira & Romero, 2017), such as cyber-physical systems (CPS), Internet of Things (Internet of Things-IoT), Internet of Services (IoS), Robotics, Computer-Aided Design (CAD), Big Data Analytics, Cloud Computing, Augmented Reality, and so on.

In this regard, the research subject in this paper are the conditions for the development of I4.0 in Serbian manufacturing industry. The main research objective is to point out the importance of efficient development of Industry 4.0 and implementation of structural changes through the process of digitalization and application of technological innovations in the manufacturing industry of the Republic of Serbia.

2. Development and Characteristics of Industry 4.0

I4.0 is described as digitalization or full automation. It is also defined in relation to new technologies. Although digitalization has led to I4.0, it cannot be defined solely through the technological paradigm, due to the convergence of industries, transformation of businesses, changes in business models, organization and culture (WEF, 2016).

The way the Internet creates tremendous value by connecting people virtually, the Internet of Things does this by connecting things. "Cyber-physical systems lead to smart manufacturing, with intelligent products, machines, networks and systems that independently communicate and interact with each other during the manufacturing process. The advances in digital technologies and their impact on I4.0 are profound, leading to a change in boundaries between industry and other sectors, as well as between buyers and sellers. What is more, the roles of the public and private sectors change, as well as the conditions of market competition. Current production systems, driven by global value chains, become more dynamic, flexible, efficient and sustainable, with personalization capabilities" (Stankovic, et al., 2017).

The concept of I4.0 was introduced by the German Scientific Research Association in 2011, and comes from the German government's strategic initiative aimed at digitalizing the manufacturing industry, i.e. creating a production process completely independent of man (Buhr, 2015). It is a strategic initiative within a high-tech strategy, and the goal is for SMEs to take advantage of I4.0 capabilities, especially in the areas of standardization, norms, security, legal frameworks, research and workforce transformation.

The I4.0 concept is "a comprehensive concept and new trend in the manufacturing industry and relevant sectors, based on the integration of a range of technologies that enable the ecosystem of intelligent, autonomous and decentralized factories and integrated products and services" (Stankovic, et al., 2017). The I4.0 concept is also associated with "smart data and information gathering and deployment in real time, as well as networking of all elements, to reduce operation complexity, increase efficiency and effectiveness, and reduce costs over the long term" (Santos, et al., 2017).

I4.0 goal is to turn machines into self-aware ones to improve maintenance, performance and interaction with the environment. I4.0 aims to build an open, smart manufacturing platform for deploying information across an industrial network. The main requirements of I4.0 are real-time data monitoring, product monitoring and positioning, and management of production process control instructions. I4.0 is an emerging structure where CPS uses a global ICT network for automated information sharing, with production and business processes aligned. The main drivers of I4.0 are the Internet of Things, the Industrial Internet of Things, the Industrial Cloud and smart manufacturing, which helps transform the manufacturing process into a digitalized and intelligent production model (Vaidya, et al., 2018).

I4.0 concerns the development phase in the organization and management of the industry value chain. I4.0 consists of nine pillars linking production into an integrated, automated and optimized flow, resulting in greater efficiency and change in supplier, manufacturer and consumer relationships, as well as between humans and machines. The nine pillars are: (1) Big Data and Big Data Analytics, (2) Autonomous Robots, (3) Simulation, (4) Horizontal and Vertical System Integration, (5) Industrial Internet of Things, (6) Cyber Security and CPS, (7) Cloud, (8) 3D printing, (9) Augmented reality (GTAI, 2014; Vaidya, et al., 2018; Xu, Xu, & Li, 2018).

The I4.0 concept is being implemented in the EU, especially in the German industry. In the US, I4.0 also uses the terms Internet of Things, Internet of Everything and Industrial Internet. What they have in common is that industry and manufacturing are influenced by digitalization. For now, I4.0 is more of a vision than a reality, but it has an impact on business digitalization so that machines do most of the work as people develop and control them. While traditional manufacturing methods and factors retreat, innovators make progress. New business and organizational models, products, services, and distribution channels develop. People, processes, services and data network, and production become faster and more flexible. Productivity grows because resources are used more efficiently (Finance, 2015).

The concept of I4.0 contributes to productivity growth through ICT-based real-time control and the use of robots. Key success factors are knowledge, flexibility, creativity and innovation. The application of ICT in industry is increasing, leading to the development of manufacturing processes. The state should support I4.0 with appropriate policies, with other stakeholders who need to embrace the importance of innovation for digitalization, because change does not only affect industry, but the whole economy (Stankovic, et al., 2017). Digitalization of manufacturing in factories also creates new skill requirements, with automation leading to redundancies while creating new jobs (Links, 2013).

I4.0 is the result of digitalization where everything in the value chain is networked with direct information exchange. The consequences of I4.0 are automation, decentralization, new business models, accelerated value creation process, flexibility, transparency, personalized production, more efficient use of resources. The larger the company, the more seriously it takes the need for digitalization, while SMEs lag behind (Buhr, 2015). The main features of I4.0 are interoperability, virtualization, decentralization, real-time functioning, service orientation and modularity (Smit, et al., 2016).

In addition to industry, I4.0 has an impact on services, business models, market, work environment, skills (Pereira & Romero, 2017). I4.0 has the biggest impact in the manufacturing industry through productivity and competitiveness growth. Structural changes in the manufacturing industry are influenced by digitalization and automation, as well as the integration of manufacturing sites into a comprehensive value chain (Roblek, Meško, & Krapež, 2016).

The potential for I4.0 is huge, taking into account individual requirements and customization of products. Faster and more flexible production reduces the use of resources and risks, highlights its own benefits, facilitates data processing, increases quality, reduces manufacturing errors, develops infrastructure. All this contributes to the creation of greater added value (Finance, 2015).

In I4.0, data collection and analysis is the standard for real-time decision making. Collecting and analyzing data between machines brings a faster and more flexible process of producing higher-quality products at lower costs, modifying the workforce profile. This leads to productivity growth, competitiveness and industrial growth. Productivity levels determine the rate of return, the rate of economic growth and the growth of investment (WEF, 2018).

New technology brings greater efficiency and changing relationships between suppliers, manufacturers and customers, as well as between humans and machines. The production uses robots for complex operations, as well as simulations for creating virtual models, which allows testing and optimizing machines before deployment, thus reducing production time. This means faster response to consumer needs, improving flexibility, speed, productivity and production quality. The connection between machines and humans requires new standards that define the interaction of these elements in the digital factory of the future (Rüßmann, et al., 2015).

I4.0 starts with production in the manufacturing industry, but its impact extends to other segments of society, including utilities, smart buildings, roads, cities, where activities are coordinated to meet the increased energy needs of smart grids. New technologies develop to manage the broad ICT infrastructure (Stankovic, et al., 2017).

The fourth industrial revolution is causing radical changes in the industry. The breadth and depth of these changes transforms the system of production, management and public administration. Today, it is impossible to predict all the potentials of I4.0 (Lodder, 2016). It is still partly a visionary conception. There are certain challenges that arise during its development such as: (1) intelligent decision-making and negotiation mechanisms, (2) smart high-speed wireless network protocols, (3) industry-specific big data and analytics, (4) system modelling and analysis, (5) cyber security, (6) modularized and flexible physical objects, (7) size problems (Vaidya, et al., 2018).

3. Change in the Industrial Paradigm and Workforce Competences in the Digitalization Era

I4.0 is a shift in the production paradigm from centralized to decentralized smart manufacturing. It computerizes production and creates smart factory (the factory of the future), in which physical objects are integrated into the information network. Production systems are vertically networked with business processes in factories, and horizontally linked to real-time value-creation networks, managed from the moment of order to outbound logistics. "This interaction between implemented systems, based on special software and the user interface, which is integrated into digital networks, creates a new world of system functionality for horizontal and vertical integration" (Chukalov, 2017).

The distinction between industry and services is increasingly blurred. Digital technologies are linked to products and services into hybrids. In smart factories, CPS and networks monitor physical processes, create virtual physical systems, and make decisions. By using IoT and CPS, systems communicate and interact with each other and with people, while through IoS, participants in the value chain offer and use internal and inter-organizational services. Smart data is collected throughout the product life cycle. This optimizes smart, flexible supply chains and distribution models, and leads to efficient and optimized use of machinery and equipment. Businesses are able to make faster, smarter decisions, responding quickly to requests, while minimizing costs (Stankovic, et al., 2017).

It is expected that I4.0 will in the long run in four ways affect the changing industrial paradigm as well as the structure of the manufacturing industry. Above all, by changing and improving the relationship between factories and nature, factories and the local community, factories and value chains, and factories and people (Santos, et al., 2017).

Changing industrial paradigm comes from new technologies that make it possible to produce faster and cleaner products, at a lower cost. Higher newly created values will be the result of innovation, and technologies will reshape production, the way additive manufacturing does. When technological solutions are fully integrated into products and networks, they facilitate the ways in which products are designed, manufactured, offered and used. The difference between cheap mass products and pricier custom products will drop due to the number and types of products. New digital technologies will bring personalization with a direct customer contribution to the design, allowing custom products to be produced in shorter production cycles, at a lower cost. The producer and the buyer will work together to create new value (Foresight, 2013).

I4.0 development and the digitalization of the economy require a wide range of value chain skills, and a whole new approach to education (Smit, et al., 2016). Digitalization and new technologies change both the type of workers and the type of skills required. Smart manufacturing requires workers with multidisciplinary knowledge, i.e. hybrid capabilities that include technical specialization and business awareness (Foresight, 2013).

The EU is of the view that competence in science, technology, engineering and mathematics is becoming an important part of literacy in the knowledge economy. Formal and informal education and knowledge acquisition in natural sciences are important in order to raise awareness of various technologies, and to respond to the challenges of STEM (STEM Education, 2019).

STEM defines the areas in which I4.0 professionals will develop, and the most successful will be those that connect multiple areas. Sustainable interaction between the various educational institutions, research and innovation funding institutions, the practicing industry, as well as policymakers (European Commission, 2019a) is important. Research has shown that the employment of STEM workforce in the EU is on the rise, but that there are differences between member states and that part of the increase is a result of migration policy and labor mobility (Caprile, M. et al., 2015). In 2016, the EU launched digitalization and implementation of measures to create a single digital market. Part of the measures refers to digital skills (European Commission, 2019b).

The EU seeks to identify the challenges of digitalization, strengthen the role of industry and research organizations to take action. It seeks to improve the understanding of the skills needed for new technologies, which is part of Horizon 2020, which promotes the development of digital skills, and to launch the creation of digital innovation centers (European Commission, 2019c).

Research on EU member states' prospects for the development of I4.0 based on digitalization by criteria of industrial excellence and value networks shows four groups of economies (Dujin, Geissler, & Horstkötter, 2014):

(1) Leaders – Members who are making good progress in the digitalization and development of I4.0 (Germany, Sweden, Austria and Ireland);

(2) Potentialists – Members where the industrial base is weak but the corporate sector is modern and has potential (UK, France, Belgium, Denmark, the Netherlands);

(3) Traditionalists – Members with a large industrial base, but few of which have initiated the development of I4.0 (Czech Republic, Slovakia, Slovenia, Hungary and Lithuania);

(4) Undecided – Members with an industrial base but low financial capacity to develop I4.0 (Italy, Spain, Estonia, Portugal, Poland, Bulgaria and Croatia).

4. RESEARCH METHODOLOGY AND HYPOTHESES

The analysis method is used to identify the concepts of I4.0 and the new industrial paradigm. The synthesis method is applied when integrating elements of I4.0 concepts and technological changes into a single whole and conclusions. The comparative method is used when comparing technological criteria and changes, manufacturing industry of the Republic of Serbia and selected EU member states.

The concept of I4.0 mostly concerns the digitalization of the manufacturing industry and the development of a range of new high technologies. In order to examine the conditions of development of I4.0, the paper analyzes technological changes and innovations, which are diverse and dominantly shape all areas of production. The complex nature of technological change in industry can also be explained by the characteristics of innovation (Evangelista, et al., 1997). The connections and relationships between I4.0 innovation and development are complex in nature and will therefore be the result of an indirect analysis of technological criteria (Galindo-Rueda & Verger, 2016). Some of the relevant criteria are process sophistication, quality of workforce, innovation, patents, added value and openness of the industry (Dujin, Geissler, & Horstkötter, 2014).

The paper uses the survey on innovation, individual innovation and technological indicators and composite indicators in the assessment and innovation processes. The most commonly used innovation measurement survey is the Community Innovation Survey (CIS) (Biagi, Pesole & Stancik, (2016). Indicators are mostly covered by high-tech statistics in the knowledge-intensive industry, with employment, science, technology, innovation, patents, based on technological intensity. The sectoral approach is used to identify the intensity of technology, which groups the activities of the manufacturing industry according to the degree of technological intensity, i.e. the amount of investment in research and development, with a production approach that considers the level of technological intensity of products and trade in high-tech products. The list of products is based on R&D intensity and total sales. High-tech product groups are determined on the basis of the Standard International Trade Classification. Total R&D expenditures in GDP are important indicators of the conditions for the development of science, technology, production, and digitalization tech-intensity, which is one of the key indicators of the Europe 2020 Strategy.

Composite indicators of the productive capabilities of industries that measure technological change used in the analysis are the Summary Innovation Index (SII), the Knowledge Economy Index (KEI), the Global Innovation Index (GII), the Global Competitiveness Index (GCI 4.0) and the Competitive Industrial Performance Index (CIP).

In order to determine the conditions and the potentials for the development of Industry 4.0, especially in relation to EU members from Central Europe with a large industrial base, the following hypotheses are tested in the paper:

Hypothesis 1: Innovation processes influence technological changes, improve and increase technological level of production of manufacturing industry in Serbia.

Hypothesis 2: Investment in R&D affects the digitalization of the manufacturing industry in the Republic of Serbia

Data from Eurostat, EBRD, WIPO (World Intellectual Property Organization) and UNIDO databases is used in the analysis of selected EU member states and Serbia.

5. RESEARCH RESULTS AND DISCUSSION

According to CIS, the share of manufacturing industry companies in the Republic of Serbia that introduced at least one type of innovation was about 43.2% in 2016, so it can be concluded that manufacturing industry is innovative (Table 1). Although the share is below the EU average and above the share of some of the observed members, especially from the region, this share is well below the leading members in the process of digitalization and transformation. However, when it comes to product and process innovation, the share of innovative businesses is much lower. Technological innovation of products and processes is insufficient, with inefficient mechanisms of practical application of the manufacturing industry research results.

Table 1 CIS – Manufacturing enterprises that have introduced an innovation, 2016 (%)

	All types	Product innovative
EU28	53.2	11.1
Bulgaria	25.1	6.8
Czech R.	44.9	8.4
Croatia	47.5	5.1
Hungary	27.6	8.3
Romania	9.8	1.2
Slovenia	37.4	10.0
Slovakia	29.3	7.3
R. Serbia	43.0	14.5

Source: Author's calculation based on Eurostat database, 2019

The economy and industry of the Republic of Serbia belong to the group of countries that are moderate innovators and whose innovative performance has increased since 2011. Relative performance relative to the EU was 63.7% in 2018 (Table 2). According to the dimensions of SII, the Republic of Serbia is below the EU average, with the best results in the area of enterprise investment, owing to the level of innovation expenditures of enterprises not related to R&D. The most disadvantaged position is in the area of intellectual property and the research system (Hugo, Nordine & Iris, 2019). The comparison shows that Serbia has a higher SII than some selected EU member states, but significantly lower values than the members with a large industrial base, which indicates modest innovation performance of the manufacturing industry.

Table 2 Indicators of innovative and productive ability, 2018.

	SII	KEI	GII
Value	0 min -100 max	1 min-10 max	0 min -100 max
Czech R.	89.4	6.28	49.43
Hungary	69.0	5.33	44.51
Slovenia	87.6	6.65	45.25
Slovakia	69.1	5.40	42.05
Romania	34.1	5.01	36.76
Bulgaria	48.7	5.18	40.35
Croatia	59.6	5.62	37.82
R. Serbia	63.7	5.13	35.71

Source: Author's based on Hugo, Nordine & Iris, 2019, EBRD, WIPO, 2019

KEI is an aggregate indicator that measures the ability to develop a knowledge-based economy and industry. According to the EBRD, in 2018, the KEI value for the Republic of Serbia was 5.13 (Table 2). It ranked 13th out of 37 ranked states. It has the best record in the ICT infrastructure pillar (EBRD, 2019). With the exception of Romania, according to the value of KEI, the Republic of Serbia lags far behind all selected EU member states, especially those with developed industries, with almost all pillars of the knowledge economy.

Serbia has the lowest GII value compared to selected EU member states, although it has improved in value but not the rank since 2011 (Table 2). According to GII, out of 129 countries, the Republic of Serbia ranked 62nd in 2018. The value of innovation inputs is greater than innovation outputs. With innovation inputs, the best result is with institutions and human resources and research. On the side of innovation outputs, values are greater in the field of knowledge and technological outputs than in creative outputs (WIPO, 2019).

According to the GCI 4.0 methodology for the competitiveness of economies, innovation at all levels and the development of human capital are needed at the time of I4.0 development. Of the four groups of factors, innovation concerns the dynamic environment and the ability to innovate, i.e. the ability to create and apply new technologies and innovative products, as well as to conduct quantitative R&D. What is good for the growth of the competitiveness of the Serbian economy is the growth of the rank and value of the pillar of innovation, where at the level of individual pillars business dynamics recorded 54th, and the ability to innovate 59th position out of 141 ranked countries in 2018 (Table 3). Pillar ability to innovate has the lowest value among GCI 4.0 pillars. The innovation pillar saw growth in value due to a slight increase in inventions, patents, R&D expenditures in GDP, as well as the development of clusters and increased collaboration between employees, businesses and universities. However, the comparison points to a large gap between the rank and value of the two pillars in comparison to EU member states. The reason, when it comes to product and process innovation, is the low share of innovative manufacturing industry companies. The rise in value is primarily in the purchase and transfer of new products and processes, digital technologies, not their development through internal R&D activities, which is the case in other observed industries.

Table 3 GCI- 4.0 Innovation Ecosystem, 2018.

	Business dynamism		Innovation capability	
	Rang/141	Value	Rang/141	Value
Germany	5	79.5	1	86.8
Slovenia	26	70.1	28	58.2
Czech R.	32	68.7	29	56.9
R. Serbia	54	63.1	59	40.2
Slovakia	55	62.8	44	46.3
Bulgaria	61	61.9	48	45.0
Romania	72	59.7	55	42.3
Hungary	83	58.1	41	47.4
Croatia	101	54.7	73	37.8

Source: WEF. (2019). The Global Competitiveness Report 2019. WEF.

Despite the rise in value and the improvement of rank, as measured by the CIP index, the competitiveness of the manufacturing industry of the Republic of Serbia is low. With a CIP value of 0.0416 in 2018, it has the lowest value and ranking of competitiveness, i.e. the worst performance against EU members. That it is low and does not sufficiently improve the competitiveness of the manufacturing industry is confirmed by the fact that of 41 ranked European countries, Serbia was ranked 31st in 2017 (Table 4). The value of the CIP index changes little due to its slow change in the short term due to technological changes that are not intensive enough in the Serbian manufacturing industry and supported by technological innovations.

Table 4 Rank and value of CIP index in 2018.

	Rank in Europe		CIP index	
	2012	2018	2018	Δ2012
Czech R.	11	11	0.2148	-0.0067
Slovakia	16	15	0.1604	-0.0103
Hungary	17	16	0.1493	-0.0085
Slovenia	21	18	0.1109	-0.0055
Romania	22	22	0.1015	-0.0109
Croatia	30	28	0.0552	0
Bulgaria	31	29	0.0524	-0.0023
R. Serbia	35	31	0.0416	0.0109

Source: Author's calculation based on UNIDO database. 2019.

High-tech manufacturing in the manufacturing industry of the Republic of Serbia employed 0.5% of employees in 2018, while this percentage in the EU was 1.1 (Table 5). The share differs significantly from the observed EU member states, and even more so when looking at the number of employees per 1,000, with Hungary and the Czech Republic ahead, while R. Serbia has only 14 per 1,000 employees. In the EU, the average employment growth rate in the high-tech industry was negative during 2011-2018. There are differences among members when comparing employment changes. Some have seen a decrease as a result of the economic crisis. R. Serbia saw a slight increase in high-tech production.

Table 5 Employment in high-tech manufacturing. 2018.

	Total in 1000's	% of total employment	Δ2011
EU28	441	1.1	-0.4
Bulgaria	22	0.7	-2.4
Czech R.	88	1.7	2.1
Croatia	12	0.7	-1.4
Hungary	114	2.6	0.7
Romania	71	0.8	4.3
Slovenia	20	2.0	2.3
Slovakia	39	1.5	-1.1
R. Serbia	14	0.5	0.6

Source: Author's calculation based on Eurostat database. 2019

High-tech products accounted for 15.4% of total EU exports in 2018, with considerable differences between member states (Table 6). The highest share, as well as the increase in the share of high-tech products in the observed period, was recorded in Ireland, Germany, and Austria, as the leaders of digitalization, but also countries with a large industrial base, such as the Czech Republic and Hungary, which recorded the largest decrease in share. It is clear that in terms of quality and export of high-tech products, the manufacturing industry of the Republic of Serbia is lagging behind the EU member states. Exports are dominated by products that are intensive with natural resources and low skilled and cheap labor.

Table 6 Exports of high technology products as a share of total exports

	2011	2018	Δ2011
EU28	15.4	17.9	2.5
Bulgaria	3.7	5.9	2.2
Czech R.	16.4	17.8	1.4
Croatia	5.8	8.1	2.3
Hungary	20.9	15.6	-5.6
Romania	8.8	8.4	-0.4
Slovenia	5.3	5.8	0.5
Slovakia	6.6	9.6	3.0
R. Serbia	2.0	1.9	-0.1

Source: Author's calculation based on Eurostat database. 2019

Exports of high-tech products from the Republic of Serbia are significantly different from EU members. The Electronics-Telecommunications and Aviation product groups account for 29.2% of high-tech exports, one-and-a-half times lower than the 2017 EU level. Pharmaceuticals follow with 15.1%, computers with 12.9% and Scientific Instruments with 11.8%. Other groups account for 31% of exports (Table 7). The fact is that the technological level of production has not improved, and digitalization is a condition for raising the share of high-tech products and increasing their exports. Intensive structural changes are needed in the forthcoming period, which would increase the technological level of production and exports, through domestic innovations and their commercialization, as well as technology transfers from abroad.

Table 7 Exports of high-tech group of products as a share of total exports, 2017.

	Electronics-telecommunications	Aerospace	Computers	Pharmacy	Scientific instruments	Other
EU28	28.2	17.5	12.4	18.7	13.4	9.8
Czech R.	43.0	2.8	38.8	1.8	6.3	7.3
Slovenia	25.6	4.6	7.2	26.1	15.8	20.7
Slovakia	76.6	0.2	13.2	0.9	3.8	5.3
Hungary	45.5	0.6	19.8	8.8	13.9	11.4
Croatia	19.6	2.1	3.1	47.4	7.7	20.1
Bulgaria	48.3	2.7	10.6	13.1	13.6	11.7
Romania	62.0	1.5	3.9	2.7	21.4	8.5
R. Serbia	26.6	2.6	12.9	15.1	11.8	31.0

Source: Author's calculation based on Eurostat database, 2019

The level of R&D expenditure in the EU increased from 1.24% in 2011 to 1.36% of GDP in 2017 (Table 8). The members of Central Europe seek to increase the quality of the industrial base and have significant overall R&D allocations from the manufacturing industry, while recording their growth. Despite recorded growth, data on the share of total R&D expenditures is extremely unfavorable for the Republic of Serbia. The situation is even more unfavorable when considering the share of manufacturing industry allocations for R&D. It is also a very modest expenditure in absolute terms, especially given the importance of R&D expenditures for the digitalization and development of I4.0. Therefore, the aim is to increase investment in the manufacturing industry R&D, which will enable the development and application of knowledge through the development of new products and processes.

Table 8 R&D expenditure, percentage of GDP

	All sectors			Manufacturing		
	2011	2017	Δ2011	2011	2017	Δ2011
EU28	1.24	1.36	0.12	/	/	0.17
Czech R.	0.86	1.13	0.27	0.48	0.55	0.07
Slovenia	1.79	1.39	-0.40	1.22	1.14	0.12
Slovakia	0.25	0.48	0.23	0.15	0.27	/
Hungary	0.74	0.99	0.25	0.46	0.43	-0.84
Croatia	0.34	0.42	0.08	0.13	0.26	-0.03
Bulgaria	0.28	0.53	0.25	0.03	0.2	0.07
Romania	0.18	0.29	0.11	0.09	0.1	-0.08
R. Serbia	0.06	0.32	0.26	0.01	0.02	0.17

Source: Author's calculation based on Eurostat database, 2019

Data on the share of total domestic R&D expenditure financed by the private sector is unfavorable for the Republic of Serbia because it is several times lower than in the EU member states. The situation is somewhat different when the state expenditure is taken into consideration, which is at a similar level (Table 9).

Table 9 R&D expenditure by sectors, percentage of GDP, 2017.

	All sectors	Business enterprise sector	Government sector	Higher education sector
EU28	2.06	1.36	0.23	0.45
Czech R.	1.79	1.13	0.31	0.35
Slovakia	0.88	0.48	0.18	0.22
Slovenia	1.86	1.39	0.26	0.21
Hungary	1.35	0.99	0.17	0.18
Romania	0.5	0.29	0.16	0.05
Bulgaria	0.75	0.53	0.17	0.04
Croatia	0.86	0.42	0.19	0.25
R. Serbia	0.87	0.32	0.24	0.32

Source: Author's calculation based on Eurostat database, 2019

In most of the countries observed, the private sector contributes with over 0.5 to R&D expenditure, while this percentage in the Republic of Serbia in 2017 was 0.32% of GDP. The reason is the lack of integration of the private sector into the innovation system. The private sector in the EU member states seeks to expand and enhance the structure of the industrial base and increases the relative allocations of the private sector to domestic R&D expenditures, which enhances the process of digitalization and the creation of a single digital market. It can be estimated that R&D allocations, both private and public, as well as allocations for science in the Republic of Serbia are not at the level that could make a significant contribution to creating conditions for the process of digitalization and development of I4.0.

Patents represent R&D results and are indicators of inventive activity, yet indirectly show the results of innovative activities. R. Serbia has a low patent activity compared to the observed EU members (Table 10).

Table 10 Patent Applications, 2018.

	Resident	Non-Resident	Abroad
Czech R.	921	54	1,330
Slovakia	267	14	293
Slovenia	355	23	383
Hungary	529	36	811
Romania	1,150	47	351
Bulgaria	212	18	247
Croatia	135	15	66
R. Serbia	172	11	136

Source: Author's based on WIPO, 2019.

According to the number of resident patent applications, Croatia had worse results than Serbia in 2018. The low inventive activity of residents is due to the low investment in R&D, the small number of researchers and the underdevelopment of the industry. The inventive activity of non-residents is also very low due to patent regulation and competition. This is the reason for high filing abroad.

6. Conclusion

The fourth industrial revolution is the emerging one and is about the development of I4.0 or smart industries and factories. It is based on a number of emerging trends and digital and other technologies. The fact is that it is now impossible to predict all the potentials of I4.0. What is certain is that countries will develop I4.0 at different speeds and modes, directing the process of digitalization and re-industrialization. The fourth wave of technological advancement due to digitalization is benefiting the industry by increasing productivity, value added, employment and investment in R&D, manufacturing new products, and rise in productivity, affecting economic development.

The new paradigm of industrial production will be not only a condition of productivity growth, global industrial competitiveness, but also of transformation and development of markets, qualifications and education, and sustainable development of society as a whole. Just as all the previous radical technological novelties have formed the structural basis for this revolution, so I4.0, in the future, will enable the development of the next technological revolution, new industries, the paradigm of industrial production and new production effects.

Data from innovation surveys, technological indicators and criteria, both individual and composite, indicate that the technological level has not improved or that no effective technological changes have been made. This does not confirm the first hypothesis that innovation processes influence technological changes, improvement and increase of technological level of the Serbian manufacturing industry. The reason is the insufficient number of technological innovations of products and processes, but also the practical application of the results of domestic scientific and research activities. Data on R&D expenditures at the sector level, especially in the manufacturing industry, as well as patents and inventive activity, also do not confirm the second hypothesis that the digitalization of the manufacturing industry in the Republic of Serbia is affected by investing in R&D.

EU member states with a large industrial base in Central Europe create conditions for the transition of the manufacturing industry, based on natural and physical resources, into industries based on intellectual resources, application of knowledge and new digital technologies, resulting in I4.0 and smart future factories that are high-technology-intensive. The analysis confirms transition and digital transformation. The creation and effective use of digital and new technologies is important in the global competitiveness of the observed EU member states. High-tech industries and smart businesses will be the drivers of their economic and productivity growth, and will increase competitiveness, structure and level of added value and employment. In these EU member states, industrial policy develops I4.0 and at the same time drives re-industrialization.

An important research finding indicates that the conditions and potentials of I4.0 development are very small compared to the EU member states in Central Europe with a large industrial base, and even more modest than the old members which are making good progress in the digitalization and development of I4.0. Digitalization in the Republic of Serbia is not driven by the results of science, technology and innovation. The re-industrialization of the economy needs to be done on these grounds. The obtained research findings are very useful for industrial policy makers in the Republic of Serbia as they point to some of the key factors and directions of change in order to create the conditions for the development of I4.0, the manufacturing industry and the digital transformation of the economy.

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USLOVI RAZVOJA INDUSTRIJA 4.0 U REPUBLICI SRBIJI

Rezime: Četvrta industrijska revolucija se odnosi na razvoj Industrija 4.0, promenu proizvodne paradigme i digitalizaciju ekonomije. Predmet istraživanja rada su uslovi razvoja Industrija 4.0 u R. Srbiji. Osnovni cilj istraživanja je da ukaže na značaj efikasnog razvoja Industrija 4.0 i sprovođenja strukturnih promena kroz proces digitalizacije i primene tehnoloških inovacija u prerađivačkoj industriji. Metod analize korišćen je za identifikovanje koncepata Industrije 4.0 i nove industrijske paradigme. Komparativni metod je korišćen prilikom poređenja tehnoloških kriterijima i promena. Uslovi razvoja Industrija 4.0 su analizirani posrednim putem preko tehnoloških kriterijuma i inovacija tj. podataka iz ankete o inovacijama, pojedinačnih inovacionih i tehnoloških indikatora i kompozitnih indikatora. Industrije 4.0 su važan faktor tehnoloških i strukturnih promena, ekonomskog rasta i konkurentnosti. Rezultati istraživanja pokazuju da nepostoje dovoljno podsticajni uslovi za razvoj Industrija 4.0 u R. Srbiji. Rezultati ovog istraživanja su korisni kreatorima industrijske politike jer ukazujuju na neke od ključnih faktora i pravaca promena kako bi se stvorili uslovi za razvoj Industrija 4.0, prerađivačke industrije i digitalnu transformaciju ekonomije.

Ključne reči: *Industrija 4.0, prerađivačka industrija, digitalizacija, inovacije, tehnološke promene*