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INDUSTRY 4.0 AS A LEVER FOR INNOVATION: REVIEW OF SERBIA'S POTENTIAL AND RESEARCH OPPORTUNITIES*

Industrija 4.0 kao poluga inovacija – pregled potencijala Srbije i prilike za nova istraživanja

Abstract

This article explores the premises of the Fourth Industrial Revolution and its role in fostering innovation and economic growth, indicating Serbia's Industry 4.0 potential and the gaps. The deployed methodology includes a literature review, both in the context of global developments and Serbia's innovation potential, supported by an analysis of several sources of empirical evidence that could serve as a basis for future research. A more in-depth investigation of blockchain and artificial intelligence (and related automation) developments, as well as a study of the application of other relevant technologies, such as robotics, cloud computing, extended reality, 3-D printing and others are suggested. The Republic of Serbia Statistical Office could support this process by conducting wider and more regular innovation surveys, as well as by adapting its business monitoring tools. It is further proposed that research focus be placed on a review of the dataset of companies and projects supported by the Innovation Fund of the Republic of Serbia, concentrating particularly on the outcomes of these projects and how they impact wider innovation activity. Finally, research should also be continued in the related fields of human capital and knowledge integration, access to finance and the regulatory and infrastructure framework.

Keywords: *Industry 4.0, innovation, Serbia, blockchain, artificial intelligence, skills, research.*

Sažetak

Ovaj članak istražuje premise Četvrte industrijske revolucije i njenu ulogu u podsticanju inovacija i ekonomskog rasta, ukazujući na potencijal, ali i jaz srpske ekonomije. Primenjena metodologija obuhvata pregled literature, kako u kontekstu globalnog razvoja, tako i inovacionog potencijala Srbije, kao i analizu empirijskih izvora koji bi mogli poslužiti kao osnova za buduća istraživanja. Predlaže se dublja studija razvoja blokčejna i veštačke inteligencije (i srodne automatizacije), kao i proučavanje primene drugih važnih tehnologija, kao što su robotika, računarstvo u oblaku, proširena stvarnost, 3-D štampanje i druge. Republički zavod za statistiku mogao bi da podrži ovaj proces sprovođenjem širih i redovnijih istraživanja o inovacijama, kao i prilagođavanjem svojih alata za praćenje poslovanja. Takođe se predlaže da se fokus istraživanja stavi na rezultate preduzeća i projekata koje podržava Inovacioni fond Republike Srbije, dodatno analizirajući njihov uticaj na šire inovacione delatnosti. Konačno, istraživanja bi trebalo nastaviti i u povezanim oblastima integracije ljudskog kapitala i znanja, finansiranja poslovanja i regulatornog i infrastrukturnog okvira.

Ključne reči: *Industrija 4.0, inovacije, Srbija, blokčejn, veštačka inteligencija, veštine, istraživanje.*

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Introduction

This article explores the premises of the Fourth Industrial Revolution and its role in fostering innovation and economic growth, indicating Serbia's potential and the gaps in this current innovation wave, and identifying areas for further research. The deployed methodology includes a literature review, both in the context of global developments and Serbia's innovation potential, supported by an analysis of several sources of empirical evidence that could serve as a basis for future research.

The global context: Evolution of innovation via the Fourth Industrial Revolution

The current stage of technological development is advanced by the Fourth Industrial Revolution, building upon the First Industrial Revolution that enabled mechanisation with water and steam power, the Second Industrial Revolution that brought about mass production and electricity-powered manufacturing assembly, and the Third Industrial Revolution based on computer-assisted automation. Unlike the first three that were initiated by invention of a new tool, be it steam engine, electricity or computers, the Fourth Industrial Revolution is an amalgamation of technologies that enable new, often distributed and smartly automated business models, fuelled by data and machine learning. The Fourth Industrial Revolution has also been described as Industry 4.0, and this term, devised by Klaus Schwab, the founder of the World Economic Forum, is used interchangeably.

Schwab first alerted to the emergence of the Fourth Industrial Revolution in a Foreign Affairs article published in December 2015, stressing that this new innovation impetus is fundamentally different from previous industrial revolutions due to the fusion of technologies and their interaction across the physical, digital and biological domains [44], [45, p. 12]. This phenomenon of technological fusion across industries, also described by Colombo et al. as "industrial cyber-physical systems (ICPS)" is purported to be "the pivotal enabler for a new era of real-time Internet-based communication and collaboration among value-chain participants, e.g., devices, systems, organizations, and humans" [12, p. 6].

Yet, as Colombo et al. warn: "The prevalent focus ought to be placed on the integration and collaboration of ICPSs not only within an organization but at large scale and within a global ICPS ecosystem" [12, p. 15]. The fourth wave of industrial innovation relies on a global scale, and occurs at a higher pace, becoming one of the key factors of economic growth and gaining and sustaining competitive advantage, both for enterprises and countries. As Bogliacino and Pianta indicate, whilst there are two "engines" of innovation-based economic growth: technological competitiveness (based on innovation in products and markets) and cost competitiveness (relying on innovation in processes and machinery), empirical studies conclude that "only science-based industries, that have heavily invested in both, can show rapid productivity increases" [5, p. 49]. Rosenberg also reminds us that economic output may be enhanced either through increasing the number of inputs that go into a productive process or by creating new ways to obtain more output from the same number of inputs, underscoring that technological innovation "continues to require the application of managerial skills of a very high order of sophistication in determining how the patterns of work might be optimally redesigned in order to exploit the vastly expanded capabilities" [40, p. 6].

According to the literature review of product development conducted by Brown and Eisenhardt [7, p. 343], internal organisation factors are critical to new product success. The authors highlight "the importance of agents, including team members, project leaders, senior management, customs and suppliers". Similarly, Brynjolfsson and Hitt [8] analysed studies and firm-level econometric evidence to conclude that the value of IT investments is dependent on organisational investments. There is overwhelming evidence pointing that knowledge integration is a precondition for achieving product innovation, including the work of Brettel et al. [6], who have shown that integration of research and development (R&D) with marketing and manufacturing positively contributes to product innovations. Bloom et al. further argue that "social capital as proxied by trust increases aggregate productivity by affecting the organization of firms" [4, p. 1663]. Analysing data on the decentralisation of investment, hiring, production, and sales decisions from

corporate headquarters to local plant managers in almost 4,000 firms in the United States, Europe, and Asia, Bloom et al. determined that "firms headquartered in high-trust regions are significantly more likely to decentralize", and that "trust raises aggregate productivity by facilitating reallocation between firms and allowing more efficient firms to grow, as CEOs can decentralize more decisions". These findings are further supported by Subramanian and Youndt's longitudinal, multiple-informant study of 93 organisations [53]. These researchers deduced that "organizational capital positively influenced incremental innovative capability, while human capital interacted with social capital to positively influence radical innovative capability" [53, p. 450]. However, contrary to their expectations, they also found that "human capital by itself was negatively associated with radical innovative capability". Social capital is hence perceived as an indispensable facilitator of knowledge integration [53, p. 450].

The strength of social capital is closely linked to the regulatory environment, with Gust and Marquez demonstrating how "burdensome regulatory environments and in particular regulations affecting labour market practices have impeded the adoption of information technologies and slowed productivity growth in a number of industrial countries", based on a panel study of 13 industrial economies for the 1992-1999 period [26, p. 33]. The underlying conclusion is that the Industry 4.0 complexity requires not only specialised technical skills, but also sophisticated managerial competence and teamwork to implement innovative technologies to optimise business processes and create new business models. The currency of this debate is confirmed by the McKinsey Digital (2020) report from the most recent Davos Forum: "Whether in process acceleration or mining throughput, AI at scale is really happening, even at large incumbent companies. […] Key to this shift is a deeper understanding that when companies implement AI, they need to pay particular attention to changing processes and how people work with the technology. A change in tech requires a change in the operating model. People are accepting the reality that, to gain full value from technology, for every dollar spent on it, multiple dollars need to be spent on change management" [34].

These conclusions endorse the more general studies such as the one conducted by Sener and Saridogan for high-income members of the Organisation for Economic Cooperation and Development (OECD), which deduced that "countries that have science-technology-innovation based economic policies and strategies have great superiority and sustainable competitive advantage in not only global competitiveness but also economic growth and development leading to wealth and welfare of the country" [47, p. 826]. Supporting this analysis, Ciocanel and Pavelescu demonstrated a strong correlation between the improved national innovation performance and the increase of national competitiveness [10]. Hasan and Tucci further investigated the importance of quality and quantity of innovation, based on global patent data for 58 countries for the period from 1980 to 2003, demonstrating that "countries hosting firms with higher quality patents also have higher economic growth" [27, p. 1264].

The impact of digitisation on economic growth is also well documented. Czernich at al., for instance, found that "a 10 percentage point increase in broadband penetration raised annual per capita growth by 0.9–1.5 percentage points in the panel of OECD countries in the period 1996–2000", which is a significant result even if the diffusion of contemporaneous technologies such as mobile telephony and computers was not measured [14, p. 505]. Evangelista et al., in turn, conducted an econometric study of composite Information and Communication Technologies (ICT) indices in the countries that were members of the European Union (EU) at the time (EU 27), deducing that "the usage of ICT, and mostly digital empowerment, exert the major economic effects, especially on employment also favouring the inclusion of 'disadvantaged' groups in the labour market" [21, p. 802]. Furthermore, Katz and Koutroumpis [29] analysed the impact of digitisation on economic growth based on a composite digitisation index including 23 individual indicators and applied on a sample of 150 countries for the 2004-2010 period. They deduced that a 10-point increase in the index produced approximately a 3% impact on the gross domestic product (GDP) for this period, resulting in an annualised effect of 0.50% [29, p. 315]. These findings corroborate another study by Sabbagh et al., who have

demonstrated that an increase in the digitisation level of 10% contributes to a rise in GDP per capita from 0.5% to 0.62%, and to a decrease in unemployment rate by 0.84% [41, pp. 125-126]. Recent research has further shown that in 17 developed countries, the first generation of robots, applied mostly in manufacturing, led to a rise in labour productivity of 0.4% a year, while digitisation has led to an annual increase of roughly 0.6 percentage points [22], [25, p. 762]. Similarly, a study analysing the impact of digitally-enabled automation and artificial intelligence (AI), key elements of the Fourth Industrial Revolution, found that they have the potential to enhance GDP growth by about 550 billion Euros, or about 1.2% per year from 2016 to 2030 in a digital front-runner country (including nine Northern European countries that are among the world's most advanced digital economies: Belgium, the Netherlands, Luxembourg, Denmark, Finland, Norway, Sweden, Estonia and Ireland) [33, p. 6]. Importantly, the study further inferred that roughly half of productivity gains would come from jobs being lost as a result of automation, while the rest would be from new products, services and opportunities enabled by new technologies [33, p. 6]. The study also affirmed that "technology diffusion contributed 0.4 to 0.6 percentage points, or around 30 percent, of digital front-runner GDP growth between 1990 and 2016, worth around 15 billion Euros a year" [33, p. 6].

Forecasts posited by experts from the world's leading research institutions also position digital technologies as drivers of economic development in the near and mid-term [45], [23], [24], [1]. An overview of the most important trends in technological development driving business innovation in the near future, as suggested by Schwab [45], Gartner [23], Deloitte [16] and Accenture [1], is provided in Table 1 below.

According to Accenture, the current "technology revolution is marked by a series of exponential technological advances. Individually and collectively these technological advances represent vast potential for the future of business, and are creating the imperative to reinvent and reimagine the way we do business" [1, p. 2]. In addition to automation and AI, another notable technology that is perceived as an enabler of progressive innovation is blockchain or distributed ledger technology noted by all the forecasts depicted in Table 1 above.

Blockchain technology is perceived as one of the catalysts of the Fourth Industrial Revolution. This technology may be described as a distributed ledger, using a network of computers (nodes), to record, share and simultaneously synchronise transactions, creating a multiparty, decentralised electronic database. The key feature of blockchain lies in this essentially immutable database, which is a basis of value chain management, constructing what World Bank depicts as "internet of value", enabling "transfer of value peer-to-peer, without a need for a centrally coordinating entity" [60]. Implementation of blockchain is currently explored across several industries – finance, energy, health, entertainment and logistics among others, including its important role in public administration. As Accenture infers, "Essentially any business that could stand to benefit from an immutable database can — and will — be disrupted by blockchain" [1, p. 54]. The blockchain market is expected to grow to over 23.3 billion U.S. dollars in size by 2023 [50]. Underscoring the significance of the rise of this new technology, a high 53% of 1,386 surveyed senior executives

Table 1: A review of the most important technological trends in the near future

Schwab (2017)	Gartner (2019)	Deloitte (2019)	Accenture (2018)
Autonomous vehicles	Hyperautomation	Digital reality	Distributed ledger technology
3D printing	Multiexperience	Cognitive technologies	Artificial intelligence
Advanced robotics	Democratisation of technology	Blockchain	Extended reality
New materials	Human augmentation	Ambient experience	Quantum computing
Internet of things	Transparency and traceability	Exponential intelligence	Technology-driven interactions
Blockchain	Empowered edge computing	Quantum computing	Technologically empowered workforce
On-demand economy	Distributed cloud	Digital reality	Cyber security
Advance in genetics	Autonomous things	Cognitive technologies	Customisation and real/near time delivery
Synthetic biology	Practical blockchain		
Neurotechnology	AI security		

in Deloitte's 2019 Global Blockchain Survey considered blockchain technology to be "a critical priority" of their organisations, representing a 10-point increase over the previous year [15]. On the policy side, blockchain is already an important consideration in many countries, and an integral part of the European Union's Digital Single Market agenda, as are other digitisation drivers, with the greatest focus placed on artificial intelligence and automation.

Digital transformation accelerated by Industry 4.0 is perceived both as a threat and an opportunity. Its unprecedented pace has raised the topic to the top of the political agenda, inevitably in conjunction with environmental and broader sustainable economic development and growth concerns. In 2019, the World Economic Forum produced a special report it aptly named Innovate Europe: Competing for Global European Leadership, openly discussing Europe's challenges of lagging behind North America and Asia in deep technologies that are critical to success in the Fourth Industrial Revolution [67]. The report proposed "ten fundamental building blocks for the competitiveness of its innovation ecosystem", focusing on the regulatory and business environment, improved financing, education and upskilling, which is in full agreement with the research findings and recommendations presented above:

1. Pan-European approach;
2. Corporate-start-up collaboration;
3. Innovation funding;
4. Enabled government and public institutions;
5. Data access and protection;
6. Entrepreneurial talent;
7. Digital education, reskilling and upskilling;
8. Gender diversity;
9. Digital infrastructure and interoperability;
10. Harmonised legislation and standards [67, p. 4].

Serbia's role in the Fourth Industrial Revolution: A review of global studies and local empirical evidence and research

Serbia is a small, transition economy in process of accession to the European Union. According to the most recent Global Innovation Index, it ranks as the world's 57th economy out of 129 observed [13]. The annual European Innovation Scoreboard (Summary Innovation Index) published by the European Commission (2019) also places Serbia as a moderate innovator in Europe, lagging behind groups of countries that fall into categories termed strong innovators and innovation leaders. In this index, Serbia is ranked as 30th out of 36 countries observed [20]. A more detailed review of Serbia's Global Innovation Index [13] reveals that Serbia achieved the best results in those indicators related to institutional framework, where it holds 47th place in the world, knowledge and technology outputs (rank 48) and infrastructure (rank 54). When it comes to human capital and research, Serbia ranks as the 59th economy, while in business sophistication, Serbia ranks as 63rd, and 65th in creative output. Serbia has achieved the poorest results (rank 103) in financing and market conditions.

The European Commission's Summary Innovation Index [20] suggests that Serbia has achieved results that are ahead of the European Union (EU) average in areas such as Enterprises providing ICT training (110.5% of the EU average), Small and medium enterprises (SME) innovating in-house (108.5% of the EU average) and Non-R&D innovation expenditures (102.1% of the EU average). The Serbian innovation climate is weakest in the areas of Design applications (2.3% of the EU average), Venture capital expenditures (3.5% of the EU average), R&D expenditures in the business sector (22.1% of the EU average) and Public-private co-publications (23.1% of the EU average). These results are aligned with the more general business climate assessment provided by the World Economic Forum's Competitiveness Report that ranks Serbia as 72nd out of 141 economies [66], and the World Bank's Doing Business Report that positions Serbia as 48th out of 190 economies [61]. According to the World Economic Forum's Competitiveness report [66], Serbia achieved the poorest results in terms of the financial system (rank 82), ICT adoption (rank 77), health (rank 76), institutions (rank 75), market size (rank 74), and product market (rank 73). Notably, in terms of innovation capability, Serbia is 59th among the observed countries. Serbia achieved the best results in the fields of business dynamism (rank 54) and infrastructure (rank 51). This report singles out the financial system as the most significant hurdle for doing business in Serbia. Institutional and

market factors are also noted as a pronounced weakness. When it comes to technology and innovation, there is vast room for improvement, especially in the field of technology and innovation in production. According to the World Bank's Doing Business report [61], the chief obstacles for businesses in Serbia are access to electricity (Serbia is ranked as 104th), protecting minority investors (rank 83) and paying taxes (rank 79). However, when it comes to starting a business, Serbia is ranked more favourably than its overall ranking (rank 40).

Considering the heightened significance of digitisation and digital transformation in today's economy, several indices have been developed that aim to assess the digital performance of countries and point to the possibilities for improvement. According to the Digital Adoption Index, developed by the World Bank, Serbia is ranked 40th in the world (out of 183 economies), performing better in this subcategory of innovation than it does on average as measured by the Global Innovation Index [59]. The Digital Adoption Index consists of three sub-indices, evaluating the adoption of digital technologies by businesses, people and government, respectively. Serbia has achieved a particularly good result in the area of digital adoption by governments, where it is ranked as 19th in the world. However, Serbia ranks 66th in the People Adoption Index, and 67th in the Business Adoption Index, which is a major concern considering that digital business services form the cornerstone of future economic development [59]. This concern is further substantiated by Serbia's score in the International Digital Economy and Society Index (I-DESI) developed by the European Commission by combining 24 indicators and applying a weighting system to rank each country based on its digital performance with the aim of benchmarking the development of digital economy and society. It measures performance in five dimensions or policy areas: connectivity, human capital (digital skills), use of the Internet by citizens, integration of technology and digital public services [19]. Serbia's overall score here is 0.50, which is nine points below the EU-28 average of 0.59 [19]. Notably, Serbia is slightly above average in some areas, as shown in Table 2 below, but generally exhibiting at best a moderate potential compared to other European economies. As shown in the previous reports, the main gap lies in business technology integration. Human capital, while representing an opportunity in the initial years of Serbia's transition, is now increasingly highlighted as a constraint.

Table 2: International Digital Economy and Society Index – Serbia and EU-28 average scores presented per each of the five dimensions [19]

Dimensions of I-DESI	Serbia	EU-28
Connectivity	0.52	0.63
Human capital	0.44	0.58
Citizen Internet use	0.5	0.6
Business technology integration	0.44	0.51
Public services	0.61	0.63

In conclusion, Serbia, while achieving progress in some areas over the last two decades, and particularly advancing in e-government services, still faces significant regulatory and institutional weaknesses which, compounded by limitations to access to finance and the skills gap, render the challenge of actively participating in the Fourth Industrial Revolution ponderous. Yet, while the gap for Serbia is significantly vaster, the same building blocks that the World Economic Forum identified for the wider European market [66] could be applied in the case of Serbia, as well. Business could additionally benefit from tech readiness models [37]. This is consistent with recommendations proposed in previous studies on Serbia's innovation and competitiveness [17], [31], [36], [42], [43], [54] [63], [64].

Yet, while there is a moderate body of literature analysing Serbia's business innovation, empirical studies are scarce. Bakator et al. [2], for instance, base their innovation analysis on a student survey on entrepreneurship attitudes (survey sample size undefined), and Cabrilo and Grubic-Nesic [9] on a survey of "79 managers holding key managerial positions in 12 service companies", with the relevance of companies determined based on company ranking published in a leading economic journal. Others also have relatively small sample sizes compared to international studies, with some of the largest including 203 women entrepreneurs [46], 106 exporters [52], and 102 companies in the agriculture and food sectors in Serbia [69], followed by 44 innovative enterprises [28]. In certain cases, the sample size is justified by the analysed segment of the economy, such as the survey of 46 women-owned

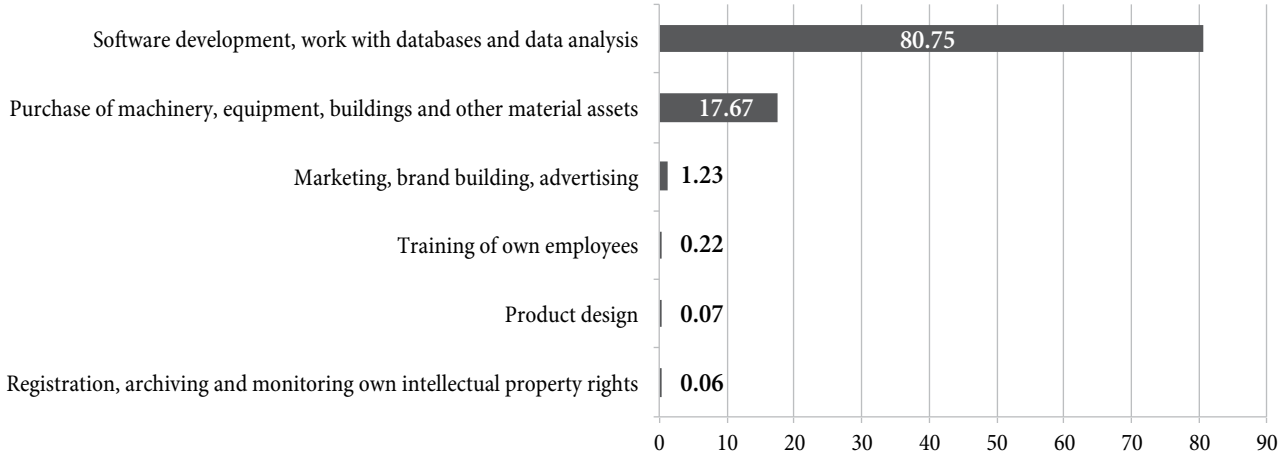
entrepreneurial businesses [39] or 52 young innovative enterprises [63]. However, even then the samples are of a size that merits interest of exclusively regional publications. Finally, some researchers analyse and interpret industry and civic organisation-led surveys conducted in Serbia. Examples include a study of the use of specific digital tools by Serbian businesses [3], or analysing evidence from surveys conducted by professional associations and civic society, such as a survey of 1,670 Serbian programmers by the SEE ICT [64]. The most comprehensive study to date of Serbia's competitiveness potential was carried out in 2007 within the framework of the USAID Serbia Competitiveness Project, including not only a detailed analysis of trade and exports data and an extensive literature review, but also a business survey of 519 managers and owners across 12 sectors (conducted by telephone by a professional survey organisation) and 87 in-person, in-depth interviews with all the relevant stakeholders conducted by expert researchers [65].

Otherwise, the majority of research studies is presented in review articles, citing global competitiveness and innovation reports alone, with several engaging in a study of wider European surveys such as the Serbian dataset from the European Manufacturing Survey [32], or combining Eurostat data, including NACE, with official Serbian statistical data [30], [35]. The size of the economy is a key reason for this research limitation, as well as the low level of participation of Serbia in the European or international sector surveys and studies. One resource lies in the World Bank's Enterprise Surveys, although this survey is also relatively limited in size and scope, with the most recent one based on interviews with top managers in 361 firms, conducted from December 2018 through October 2019, and including questions regarding innovation and technology [62]. This survey draws conclusions across global economies, and in the last edition for Serbia, it highlights the impact of firm size on innovation, with larger firms investing more resources than SMEs, when compared to other countries.

The rare empirical studies with a significant sample size (for the size of the Serbian economy) have been periodically conducted by the Statistical Office of the Republic of Serbia, namely the Indicators of innovation activities, 2016–2018 survey of 3,673 small, medium and large enterprises, which followed a similar survey conducted in 2011 [51]. There was a limited set of survey questions, with respondents underlining limited financing as a key constraint to innovation, and identifying software development as the main innovation investment area (80.75%), followed by investment in equipment and material resources (17.67%). The investment in other innovation inputs is extremely low, education included (just 0.22% dedicated to staff training). These data are presented in Figure 1.

The Statistical Office of the Republic of Serbia would considerably enhance evidence-based research and serve to better inform policy proposals relating to Serbia's innovation gaps by increasing the set of questions and conducting regular, annual innovation surveys, as well as by supporting global surveys such as the Global Entrepreneurship Monitor, which was last conducted for

Figure 1: Structure of expenditure by the surveyed Serbian companies (%) [51]



Serbia in 2009. Another important set of data that could serve as a basis for further empirical analysis pertains to innovative companies and projects that participated in the Innovation Fund of the Republic of Serbia (IF) programmes. Thus far, the IF has supported 695 innovative projects with 24.1 million Euros (total project value amounted to 33.3 million Euros) [55].

One of the most relevant IF programmes to foster science-based innovation is the Collaborative Grant Scheme, initially established with the EU support and the World Bank advisory guidance [56]. The Collaborative Grant Scheme (CGS) provides grants of up to EUR 300,000 to consortia consisting of at least one Serbian private-sector company and at least one registered Serbian public sector R&D organisation [56]. The IF-administered financing covers a maximum of 70% of total eligible project costs with a minimum of 30% co-financing provided by the beneficiaries, for projects of 24-month duration [56]. A total of 23 consortia have benefited from this programme, with the first 14 selected in 2017 and the next nine in 2019 [56]. Figure 2 shows the sector structure for the 23 awarded companies.

A similar sector structure is displayed for the 34 companies awarded through the Matching Grants

Figure 2: CGS industry/research area distribution (23 companies awarded in 2017 and 2019) [56]

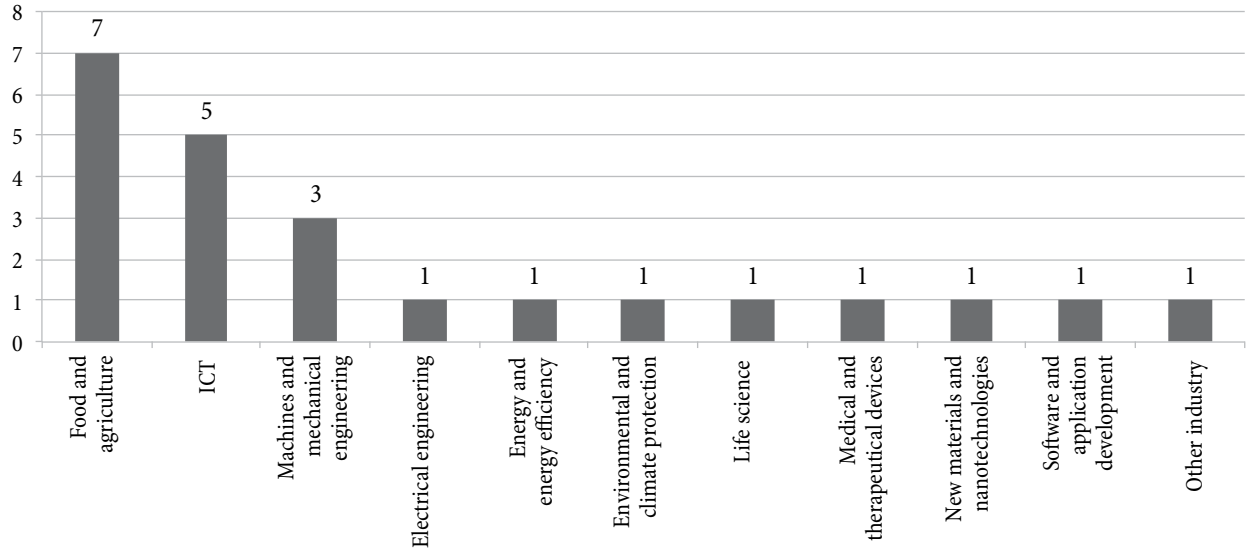
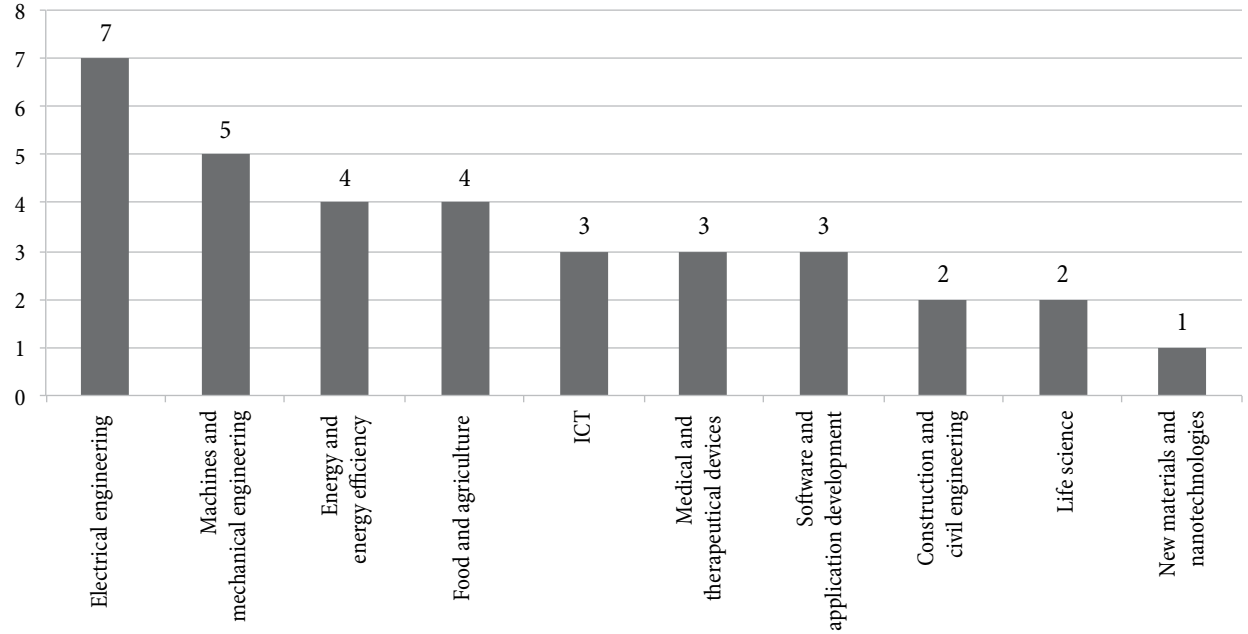


Figure 3: Matching Grants Program industry distribution (34 companies awarded from 2012 to 2019) [57]



Program, which provides up to 300,000 Euros or up to 70% of project budget for micro and small, and up to 60% for medium enterprises for the period of up to 24 months (Figure 3) [57], and the 96 companies participating in the Mini Grants Program, aimed at young private enterprises and financing up to 80,000 Euros or up to 70% of the project budget for the 12-month period (Figure 4) [58], with specialisation over time approaching that of the technology areas most demanded by Industry 4.0. The final cycle of 10 Matching Grant recipients thus includes one in each of the following categories: biotechnology and bioengineering; food; health and functional food, food supplements; heating and cooling technologies and heat transfer; industrial machines; Internet of things (IoT); radar, radio and wireless communication; robotics; software and application development (web and mobile); video data analysis. Similarly, the final selection of 23 mini grant recipients is distributed in the sectors that are more closely linked to the Industry 4.0 context (Figure 5) [57].

Figure 4: Mini Grants Program industry distribution (96 companies awarded from 2012 to 2019) [58]

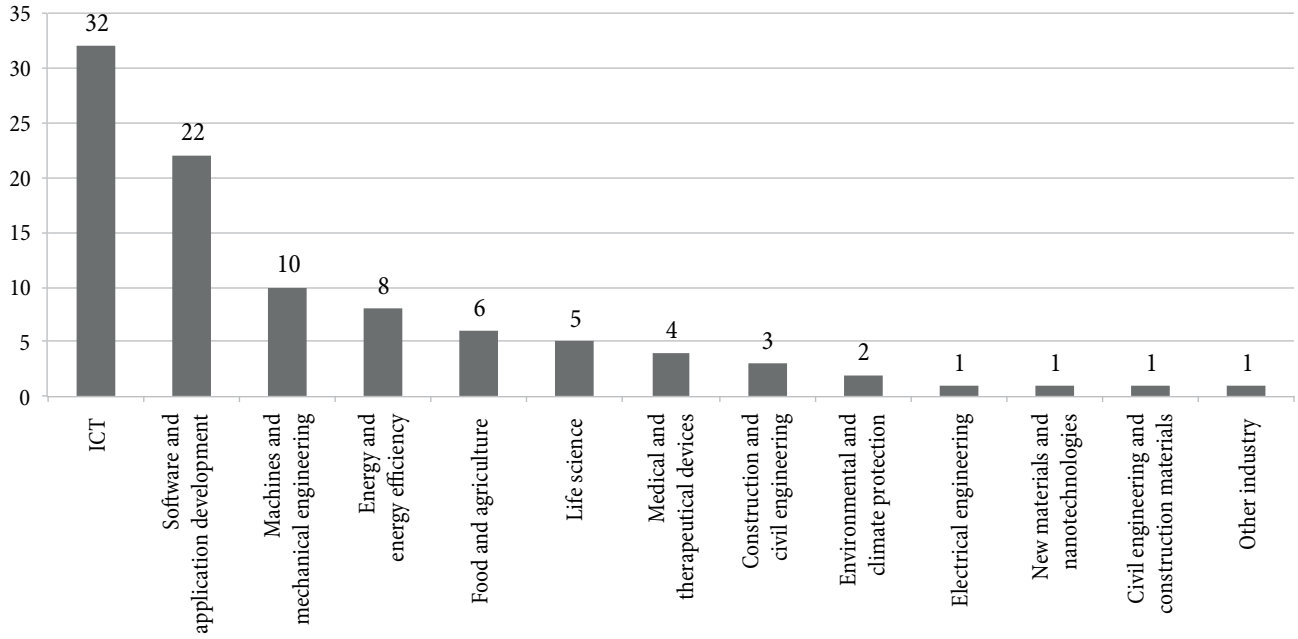
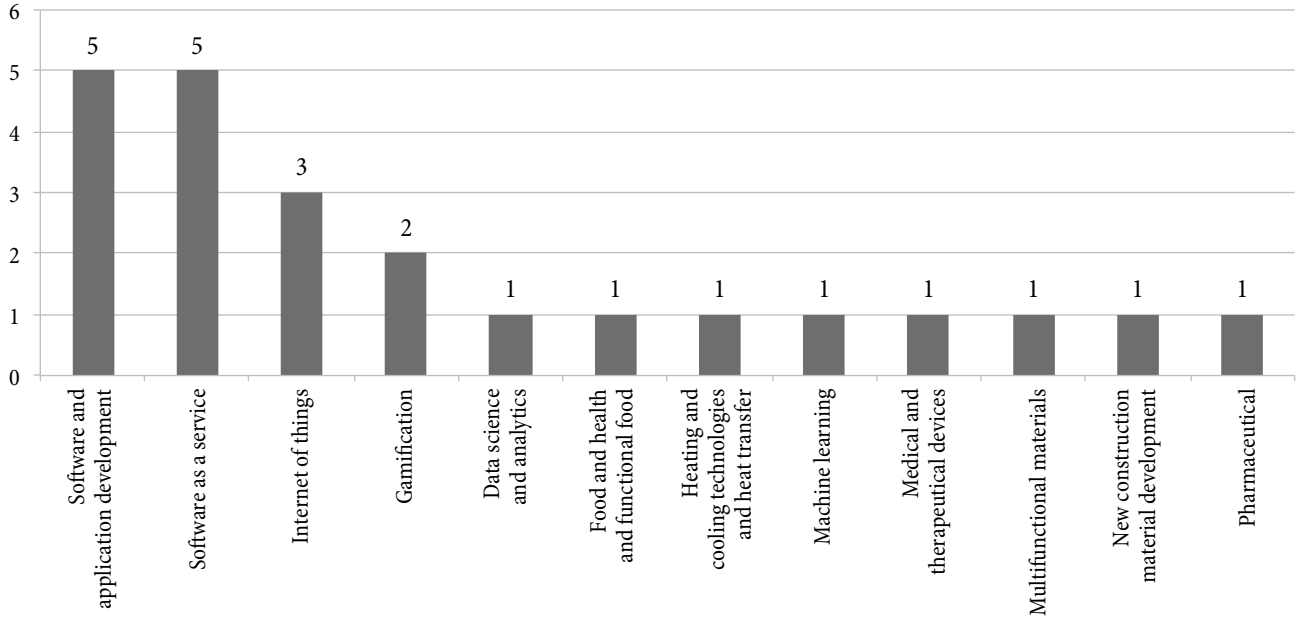


Figure 5: Mini Grants Program industry distribution (23 companies awarded in 2019) [58]



There is currently no public information on the results of these innovation projects, which would be an important subject of future research. It is likely that the overall findings would be more optimistic than when assessing the SMEs across a sector. The majority of surveyed manufacturing SMEs, for example, admits not to be using the smart, Industry 4.0 technologies [18].

The sectorial distribution of IF-supported innovative companies, especially in the recent years, matches that of the companies that the World Economic Forum proclaimed Technology Pioneers, as shown in Figure 6 and Table 3 below (annual distribution is provided in the table to clearly present changes in certain categories over time). The World Economic Forum initiated this program in 2000, and in selecting these companies an independent expert committee evaluates applicants against the following criteria:

- Innovation: truly innovative in bringing to market technology with an effective business model; considered a technology leader in its field.
- Impact: has the potential to make a substantial long-term impact on business and society.
- Growth company: less than 10 years old, observed from company inception; an independent, privately held company.
- Leadership: visionary leadership with the ability to drive the company to success, and be able to contribute with time and expertise to the Forum's work [68].

However, as even limited desk research indicates, the size of the WEF Technology Pioneer companies in terms of investment and revenues is multiple that of companies selected to receive support from Serbia's Innovation Fund (companies selected in the past include: Airbnb, Google, Kickstarter, Mozilla, Palantir Technologies, Proteus Digital Health, Scribd, Spotify and Twitter) [68].

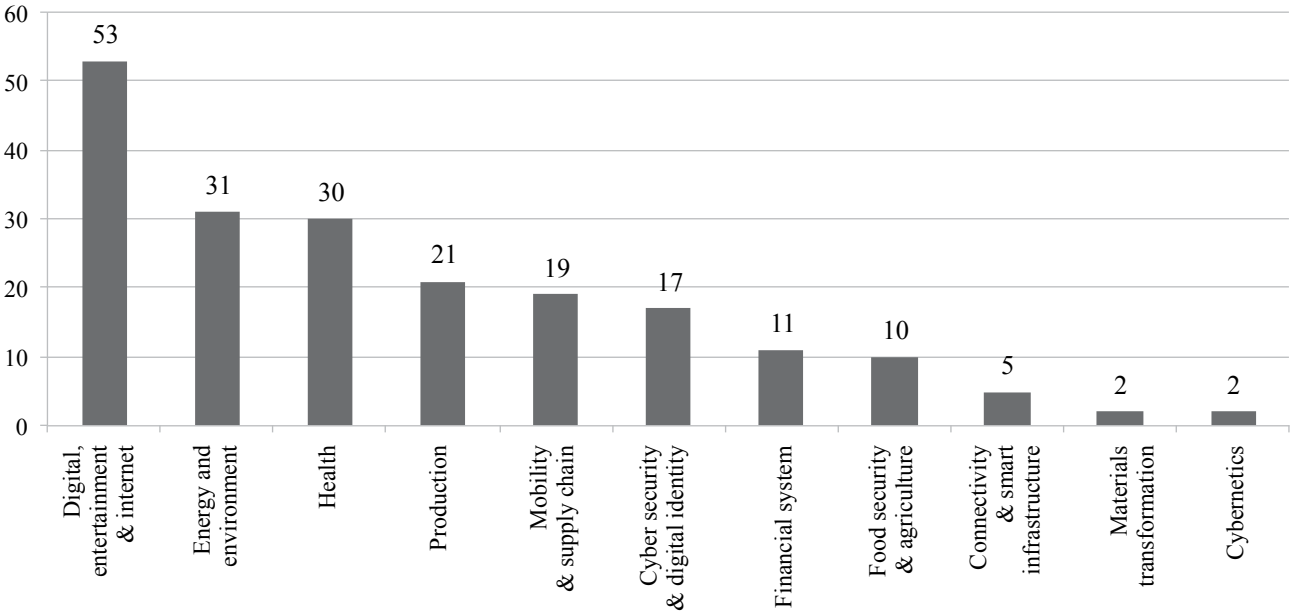
The gap is also visible when we examine the geographic distribution of WEF Technology Pioneers, based on their

Table 3: WEF Technology Pioneers sector structure (2015-2019, presented per year)

Sector	Year				
	2015	2016	2017	2018	2019
Digital, entertainment & Internet	5	9	7	19	13
Energy and environment	5	6	6	7	7
Health	5	6	5	4	10
Production	0	5	5	6	5
Mobility & supply chain	0	0	4	7	8
Cyber security & digital identity	0	0	3	8	6
Financial system	0	2	0	6	3
Food security & agriculture	0	2	0	4	4
Connectivity & smart infrastructure	5	0	0	0	0
Materials transformation	2	0	0	0	0
Cybernetics	2	0	0	0	0

Source: Authors' analysis based on WEF data [68].

Figure 6: WEF Technology Pioneers sector structure (2015-2019, aggregately presented)



Source: Authors' analysis based on WEF data [68].

headquarters' location, presented in Figure 7 and Table 4 below. The USA is dominant, followed by Northern and Western Europe. The subsequent Figure 8 provides an overview of European geographic distribution alone to highlight the role of individual countries. There is not a single Technology Pioneer seated in Eastern or Southern Europe, Serbia included. This further reinforces the need for a comprehensive study of IF-selected innovative companies in Serbia and how they compare to the global leaders.

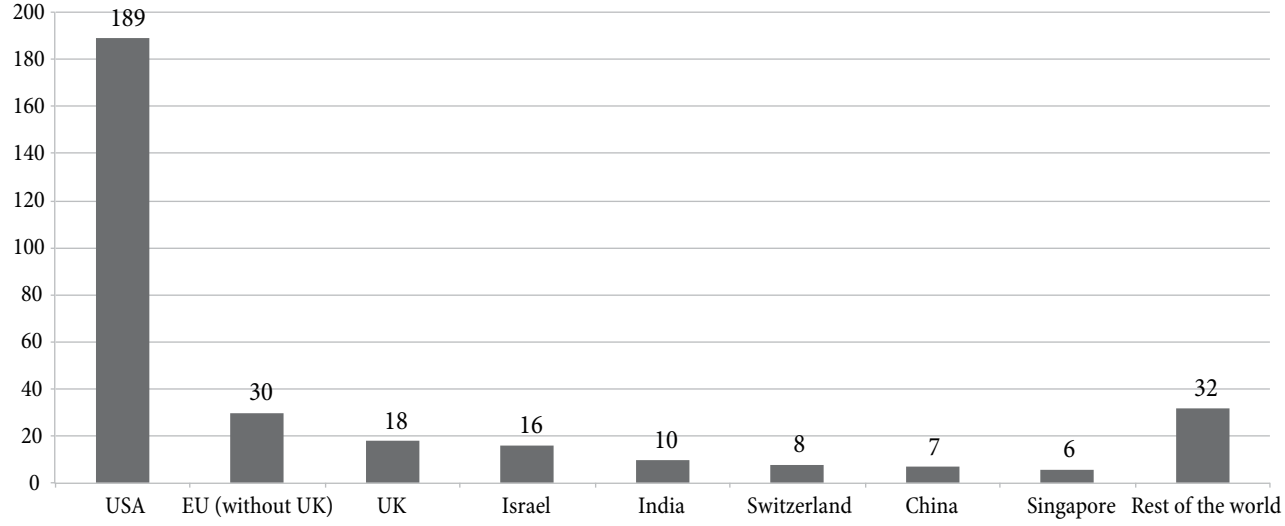
Furthermore, the state of application of Industry 4.0-enabling technologies in Serbia merits additional research attention. For a preliminary assessment of Serbia's blockchain potential, in 2019 we conducted desk research and a 20-question online survey administered

Table 4: WEF Technology Pioneers headquarters location for the countries qualified as the Rest of the world in Figure 7 (2015-2019)

Country	Number of companies	Country	Number of companies
Australia	4	Bangladesh	1
Canada	4	Hong Kong	1
Brazil	3	Indonesia	1
Japan	2	Nigeria	1
Kenya	2	Norway	1
Mexico	2	Russia	1
Morocco	2	Saudi Arabia	1
New Zealand	2	South Africa	1
South Korea	2	Thailand	1

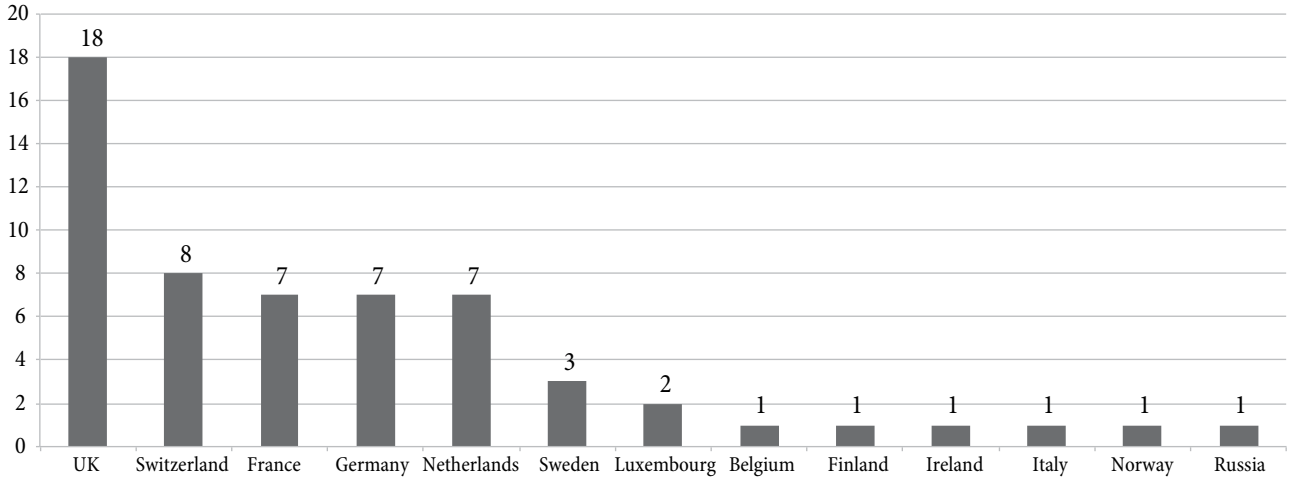
Source: Authors' analysis based on WEF data [68].

Figure 7: WEF Technology Pioneers headquarters location (2015-2019)



Source: Authors' analysis based on WEF data [68].

Figure 8: WEF Technology Pioneers headquarters location for Europe (2015-2019)



Source: Authors' analysis based on WEF data [68].

via SurveyMonkey, which was followed by qualitative, in-depth interviews held with seven key representatives of the Serbian blockchain community to overcome deficiencies of the small sample size (eight online survey respondents out of the potential 19). The Serbian blockchain ecosystem features mainly outsourcing service providers, with a limited number of companies leading their own product development. Furthermore, in the case of own product development, the main founders tend to predominantly be foreign, whilst the bulk of the financing is globally crowdsourced. In terms of sectorial focus, the primary concentration is in the finance and gaming industry, followed by supply chain management and other industries. The blockchain ecosystem is still relatively small, with possibly a dozen firms mainly employing 10 to 49 people. Importantly, however, these firms operate globally and often have international know-how and linkages to advanced economies and business processes, engaging in constant upskilling. As a result, they are an important source of Serbia's innovation potential. Yet none of the interviewed firms has received any public funding, and generally consider financing and regulatory issues a hurdle to future growth. These companies further identify marketing and sales as an area where they would require support, in addition to the increasing problem of the availability of skilled computer programmers. Furthermore, all perceive an additional skills gap in soft skills and business skills in Serbia, both in the area of product management and sales. Recognition of digital assets by the financial regulation, and improved policy around data management are highlighted as two areas of regulatory concern. Most of the surveyed and interviewed companies participate in the Serbia Blockchain Initiative and other regional or global associations in an attempt to jointly educate and resolve regulatory issues, as well as to network to improve their sales pipeline by collaborating on different projects and branding Serbia as a relevant talent pool. To assess the awareness of blockchain technology among the leading Serbian economists and corporate directors, over the same period a survey was also conducted among members of the Serbian Association of Economists and the Association of Corporate Directors of Serbia. The response rate was acceptable, but the overall sample, as in the case of the Serbian blockchain ecosystem participants, is still too limited in number to present these results as a significant empirical finding (14 respondents). Nonetheless, it is an indicative result, in that the vast majority of top Serbian economists and managers declared to be either unfamiliar with the blockchain technology or to be familiar with its basic workings. None of the respondents were aware of any Serbian blockchain companies, demonstrating a need to forge stronger corporate-start-up links, which is also identified as a World Economic Forum recommendation for wider Europe (2019).

Academic researchers in Serbia have started studying blockchain technology, mainly but not exclusively in the context of its financial applications. A search of the Serbian citation index [49] results in a total of 14 articles that denote blockchain as a keyword, with additional two articles that use the word in the body of the article.

The information on innovation activity in the field of artificial intelligence (AI) in Serbia is even scarcer. Serbia has been included in the Government Artificial Intelligence Readiness Index 2019 [38], where it is ranked as 58th out of 194 countries globally and at a regional average, with Slovenia ranking as 38th, Bulgaria as 47th, Hungary 48th, Romania 55th, followed by North Macedonia (61), Croatia (62), Montenegro (67), and finally Albania and Bosnia and Herzegovina lagging behind as 83rd and 95th, respectively. This index is comprised of 11 input metrics, grouped under four high-level clusters: governance; infrastructure and data; skills and education; and government and public services. The focus is on the business environment rather than companies' readiness. This is the only data point specific to AI that is cited in the description of the current situation in the newly adopted Strategy for the Development of Artificial Intelligence in the Republic of Serbia for the period 2020-2025 [24]. A starting point for future empirical research could be the Serbian AI Society, founded in early 2020 and convening about a dozen experts [48] and portals such as the Clutch service portal [11], which lists seven companies from Serbia that work in the area of artificial intelligence as of January 2020 (the total number of firms operating in AI listed on this portal is 1,947). For four of the companies, this is 10 or 15% of operations, while the other three firms engage

in AI to a more significant extent (40%, 55%, and 30% respectively). The size of these three most active companies is relatively small, with two employing less than 10 people and one between 10 and 49. For the sake of comparison, there are 17 AI companies listed for Bulgaria on this portal, 18 for Romania and seven for Northern Macedonia. In brief, initial desk research leads to the conclusion that Serbia's AI business community is still relatively small but growing. Researchers, on the other hand, have engaged with the topic to a greater extent than with blockchain. Although only one article in the Serbian citation index notes artificial intelligence/machine learning as a keyword, the term is mentioned in 238 articles in the body of the text, while another 14 note IoT as a keyword, with the majority of the AI and IoT publications belonging to the field of engineering [49]. Overall, the research published on Industry 4.0 technologies is relatively limited, especially when it comes to the study of the implementation of these technologies in Serbia.

Conclusions

In assessing Serbia's potential and the gaps in deploying innovating technologies that form the backbone of Industry 4.0, this article corroborates policy recommendations from both international and local innovation studies that focus on further regulatory and institutional reforms, improving access to finance, and strengthening education and skills.

Importantly, this article also identifies an immense research opportunity to engage in more comprehensive, empirical studies on business innovation in Serbia, considering the limited number and the scope of available literature on this topic published to date, especially in relation to the driving technologies of the Fourth Industrial Revolution and how local companies apply them to reach a higher level of productivity and growth. These would include a more in-depth investigation of blockchain and artificial intelligence (and related automation) developments, as well as a study of the application of other important technologies, such as robotics, cloud computing, extended reality, 3-D printing and others identified by leading analyses presented in Table 1 of this article. The Statistical Office of the Republic of Serbia could support this process by conducting wider and more regular innovation surveys, as well as by adapting its business monitoring tools. It is further proposed that research focus be placed on a review of the dataset of companies and projects supported by the Republic of Serbia Innovation Fund, concentrating particularly on the outcomes of these projects and how they impact the wider innovation activity. Finally, research should also be continued in the related fields of human capital and knowledge integration, access to finance and the regulatory and infrastructure framework.

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