Journal of Contemporary Economics (JCE)
Vol. 10, No. 1, 2026

Challenges and Opportunities of Managing Small and Medium-Sized Enterprises in Developing Countries in the Era of Industry 4.0

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ARTICLE INFO
Review paper
Received: 07th of March, 2026
Revised: 17nd of April, 2026
Accepted: 05th of May, 2026
doi:10.7251/JOCE2610067M
UDKxxx

Keywords:
Industry 4.0,
small and medium-sized enterprises,
developing countries,
challenges, opportunities
JEL Classification: D02, O17, O43, Q55

ABSTRACT
Industry 4.0 represents a transformational movement that brings significant changes to production through smart technologies, automation, and data-driven decision-making. This paper examines the challenges and opportunities faced by small and medium-sized enterprises (SMEs) in the context of Industry 4.0. SMEs can achieve substantial benefits by integrating the Internet of Things (IoT), data analytics, and other digital tools, enabling supply chain optimisation, cost reduction, and improved inventory management. Digitalisation provides SMEs with access to global markets, enhances innovation and productivity, and improves customer satisfaction. This study conducts a systematic literature review to identify the main challenges and opportunities that Industry 4.0 presents to SMEs, and to synthesise existing research to guide future studies and practical recommendations for SMEs. However, implementing Industry 4.0 also presents challenges, including high investment costs, workforce training needs, and cybersecurity risks. Governments and financial institutions can play a key role in supporting SMEs by providing accessible financing options and developing infrastructure. Accordingly, this paper provides recommendations for governments and financial institutions on how to better shape the business environment for SMEs. Further research is recommended, with a particular focus on developing theoretical frameworks, collecting reliable data, and conducting comparative studies to identify best practices and key chalenges in the adoption of Industry 4.0.

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1. Introduction

The Fourth Industrial Revolution, better known as Industry 4.0, represents a paradigm shift in production and industry through the integration of digital technologies. This integration has far-reaching impacts, spanning production lines, supply chains, and business practices (Schwab, 2017). Industry 4.0 offers significant opportunities for innovation, efficiency, and competitive advantage within industries and across the global market. On the other hand, its implementation creates numerous challenges, particularly for SMEs from developing countries.

The Fourth Industrial Revolution is characterised by future industrial development trends aimed at achieving more intelligent production processes, including reliance on and development of cyber-physical systems, as well as the implementation and operation of smart industries that utilise advanced techniques and technologies (Schwab, 2016; Zhou et al., 2016). The rapid adoption of new and emerging technologies such as the Internet of Things (IoT) and the Internet of Services (IoS) has contributed to the emergence of the Fourth Industrial Revolution. This revolution has been adopted in many countries under different terms, such as "smart industry," "advanced manufacturing," "Industrial Internet of Things," or "Industrie 4.0" (European Parliament, 2015). However, the adoption and implementation of most new technologies, as well as their promotion in society, have revealed a broader complexity that extends beyond technology itself and includes social, legal, and institutional dimensions. This multidimensional complexity requires an appropriate theoretical framework.

Digital transformation may involve acquiring new skills, competencies, and knowledge, which can prompt companies to introduce new products and processes (Radičić & Petković, 2023). In recent years, the industrial environment has undergone radical changes due to the introduction of concepts and technologies based on the Fourth Industrial Revolution (Sendler, 2013). The term "Industry 4.0" was first introduced at the Hannover Fair in 2011 as a synonym for this new industrial revolution. The focus of Industry 4.0 is on integrating manufacturing, information technology, and the internet. Accordingly, modern information and communication technologies are integrated with traditional industrial processes (BMBF, 2012). The global economy has become highly competitive for the European industry. It is no longer sufficient to produce faster, cheaper, and higher-quality products than competitors to preserve existing competitive advantages. Industry must adopt new types of innovative and "digital" production strategies to maintain long-term competitiveness (Manhart, 2013). The transformation of the customer experience for products and services indicates that digital technologies are changing how companies create value for customers. In the digital era, customers are interconnected and interact with one another, thereby transforming both their relationships with businesses and their relationships with one another (Mišić, 2024).

The Fourth Industrial Revolution is expected to extend across the entire production system and component supply chains, rather than being limited—like previous revolutions—to mechanical production processes and related organisational structures. The development of Industry 4.0 aims to address global challenges such as sustainability, efficient use of resources and energy, and enhanced competitiveness (Kagermann et al., 2013). Throughout the production life cycle, data exchange should be improved to generate benefits for all stakeholders. Customers gain greater functionality and customisation options, while supply chains achieve increased flexibility, transparency, and globalisation (Baum, 2013).

In addition, the Fourth Industrial Revolution aims to restore uniqueness in production (Hartbrich, 2014). Therefore, in order to remain competitive, the ability to respond quickly and flexibly to customer requirements and to produce a large number of product variants in small series must be enhanced (Spath et al., 2013). Industry 4.0 seeks to implement highly efficient, automated production processes, traditionally associated with mass production, within industrial environments where individualised and customer-specified products are manufactured using mass customisation strategies (Modrak et al., 2014). Mass customisation refers to the production of customer-tailored products at costs comparable to those of mass-produced goods. Production based on Industry 4.0 principles creates conditions for replacing traditional structures built on centralised decision-making mechanisms and rigid constraints within

individual value-added stages. These structures are being replaced by flexible, reconfigurable production and logistics systems that enable interactive, collaborative decision-making (Spath et al., 2013).

SMEs represent a critical component of the economic infrastructure of developing countries, making significant contributions to GDP and employment generation (World Bank Group, 2019). Governments in developing countries play a key role in creating an environment that enables SMEs to succeed in the era of Industry 4.0. Policies and initiatives aimed at improving access to digital finance, promoting digital literacy, and building innovation-friendly ecosystems are essential components in empowering SMEs to adopt digital technologies seamlessly (World Economic Forum, 2018).

This paper provides an overview of the challenges and opportunities that Industry 4.0 presents for SMEs operating in developing countries. By examining the details of this transformation process, the study offers insights into how SMEs can overcome adoption challenges and fully benefit from Industry 4.0's positive effects. The objective of this research is to analyse and identify the key challenges and opportunities that Industry 4.0 brings to SMEs in developing countries. The research examines the impact of Industry 4.0 technologies on the challenges and opportunities faced by SMEs. The research problem focuses on identifying the specific obstacles and barriers SMEs in developing countries encounter when implementing Industry 4.0 technologies. These barriers may include limited financial resources, shortages of skilled labour, inadequate infrastructure, and regulatory and institutional challenges. In addition, the study seeks to identify potential opportunities that technological innovation may offer SMEs, including increased efficiency and market expansion.

This paper provides a holistic discussion of the complexity of Industry 4.0's impact on small and medium-sized enterprises in developing countries. The study aims to contribute to the ongoing debate on building an ecosystem conducive to SME growth in the digital era. The remainder of the paper is organised as follows. The next section presents a literature review related to the challenges and opportunities faced by SMEs in developing countries. The following section explains the research methodology. Subsequently, the results are presented, followed by the main conclusions, limitations, and suggestions for future research.

The objectives of the paper are to synthesise the main barriers and enabling conditions identified in the literature and empirical data that shape Industry 4.0 adoption among SMEs in developing countries. Additionally, the paper complements the literature synthesis with empirical evidence from the World Bank Enterprise Survey (WBES) for the Western Balkan countries.

The study is guided by four research questions. First, it examines the technologies, practices, and organisational transformations most frequently associated with opportunities for SMEs in developing countries. Second, it identifies the barriers and enabling conditions that recur most consistently across the literature and systematises them within five coding domains: financial factors, technical and infrastructural conditions, skills-related constraints, governance and management issues, and the broader policy and institutional environment. Third, the study extends the literature-based synthesis through a benchmarking analysis of the Western Balkans, using quantitative indicators to assess SME versus large firm differences in digital capabilities and related performance and constraint measures. Fourth, it derives the policy and managerial interventions most strongly supported by the combined evidence from the systematic synthesis and the empirical benchmarking exercise.

Prior research has produced valuable conceptual discussions and systematic reviews on Industry 4.0 broadly and on SME digitalisation. However, two gaps remain unaddressed regarding the developing countries. First, many reviews do not report sufficiently explicit, reproducible review protocols (search strings, screening workflow, and coding rules), thereby limiting the development of cumulative knowledge. Second, the Western Balkans are rarely examined through an integrated design that connects systematic qualitative synthesis to WBES data for Bosnia and Herzegovina, Serbia, Montenegro, and North Macedonia. By addressing both gaps, the present study offers a contribution that is both theoretically structured and empirically grounded.

The contribution of this paper is threefold. First,

it provides a structured and systematic synthesis of the key barriers and enabling factors of Industry 4.0 adoption in SMEs within developing countries, organising them across financial, technological, skills-related, managerial, and institutional dimensions. Second, the study extends the existing literature by integrating qualitative insights from the systematic review with quantitative benchmarking evidence from the World Bank Enterprise Survey for selected Western Balkan countries, thereby bridging the gap between conceptual and empirical analyses. Third, the paper contributes to the literature by focusing on a relatively underexplored regional context and by highlighting the layered nature of SME constraints, emphasising the interdependence between digital readiness, investment capacity, and managerial capabilities.

2. Literature Review

Authors emphasise that Industry 4.0 creates significant opportunities for SMEs, which can use these technologies to increase flexibility, productivity, and competitiveness (e.g., Kagermann et al., 2013;). However, they also highlight that substantial investments are often required to achieve such benefits (Hatler, 2012; IBM, 2015). In many cases, particularly for SMEs, it is not easy to recognise the potential economic benefits of adopting Industry 4.0 (Koch et al., 2014; World Economic Forum, 2014). There is therefore a need to evaluate outcomes, such as increased flexibility, productivity, and market competitiveness, to measure the return on investment (ROI). This claim is supported by our literature review, which identifies data security as a major issue companies face when implementing Industry 4.0. To overcome this challenge, standards for cryptography and security models should be developed (Kagermann et al., 2013), as traditional security systems are no longer sufficient given the expanding boundaries of companies (Chen & Zhao, 2012). The development of standards and legal regulations is also essential. These should be established not only to address security concerns but also to enable faster implementation and wider diffusion of Industry 4.0. Companies often develop their own solutions, partly due to a lack of trust and fears that sharing knowledge with other firms may reduce profitability (Müller et al., 2017). However, the absence of standards leads to complex interoperability and compatibility issues among machines, companies, and infrastructures. Finally, despite the large number of publications on Industry 4.0, insufficient attention has been devoted to the development of implementation models (Liao et al., 2017); in fact, a clear methodological approach to implementation is still lacking (Geissbauer et al., 2014; Meißner et al., 2017; Schröder, 2016). To overcome this barrier, companies must cooperate and jointly develop compatible automation solutions, resulting in modular factory structures (Weyer et al., 2015).

Industry 4.0 provides SMEs with the tools needed to improve their products and services and to better meet specific customer requirements. The emergence of advanced manufacturing technologies such as additive manufacturing (3D printing) enables SMEs to develop complex components with high precision and customisation capabilities (Kagermann et al., 2013). Furthermore, by using digital twin technology, SMEs can create virtual replicas of physical assets, allowing simulation and optimisation of product design and production processes (Porter & Heppelmann, 2014). By applying these capabilities, SMEs can offer higher-quality products tailored to customer preferences, thereby increasing customer satisfaction and loyalty.

Industry 4.0 emerged as an innovation initiative in Europe, driven by policy initiatives focused on high-technology manufacturing sectors and supported by developments in business, academia, and public policy. This type of technology is based on the concept of the "smart factory," which enables the integration of physical and digital factory components, thereby increasing automation and autonomy in production processes (Schwab, 2017). The smart factory is connected horizontally across different production units and vertically throughout the supply chain, enabling digital integration of the entire value chain.

The concept of Industry 4.0 does not apply exclusively to manufacturing but also characterises the technological evolution of other sectors. More precisely, it refers to both manufacturing and non-manufacturing firms whose shared value propositions deliver products and services enhanced through the adoption of new technologies (Branco et al.,

2023). Industry 4.0 represents an advanced model of automated production systems based on connectivity and decentralised control within cyber-physical systems (CPS), utilising the Internet of Things (IoT), cloud computing, and artificial intelligence–supported data storage. It originated as a strategy for advancing digitally driven smart factories and can also be applied to SMEs, provided that risks are properly assessed and appropriate foundations for implementation are established (Majstorović et al., 2020).

Industry 4.0 creates an environment that enables SMEs to integrate into global markets, increasing their opportunities for developing new business engagements. E-commerce channels and digital platforms provide SMEs with cost-effective tools to promote their products and services worldwide, thereby bypassing traditional barriers to entry such as geographic location and distribution networks (World Bank Group, 2019). In addition, Industry 4.0 enables SMEs to participate in collaborative networks and partnerships with large corporations, leveraging their expertise and resources to enter new markets and expand operations (Kagermann et al., 2013). By connecting to global value chains, SMEs can improve input sourcing, reduce production costs, and enhance competitiveness in international markets.

Industry 4.0 also supports SMEs in accelerating innovation and responding more flexibly to rapidly changing market dynamics. Digital technologies enable SMEs to collect and process large volumes of data for accurate, data-driven decision-making and innovative solutions (Bughin et al., 2018). For example, AI algorithms can analyse consumer behaviour patterns and market trends, helping SMEs anticipate customer needs and preferences and develop products and services accordingly (Davenport, 2018). Furthermore, agile manufacturing strategies involving flexible production systems and lines allow companies to meet diverse requirements and enable real-time customisation (Porter & Heppelmann, 2014).

By fostering a culture of innovation and agility, Industry 4.0 enables SMEs to maintain their competitive position and explore new opportunities in a constantly evolving business environment. However, misconceptions about the impacts and risks of Industry 4.0 often discourage SMEs from adopting it, leading to risk aversion and hesitation about digital transformation. SMEs may be reluctant to invest in new technologies due to concerns related to compatibility, scalability, and data security (Bughin et al., 2018). Moreover, the perceived complexity and organisational disruption associated with Industry 4.0 adoption may further deter SMEs from embracing innovative digital approaches. One of the key advantages Industry 4.0 offers SMEs is access to global markets. Digital platforms and e-commerce channels provide cost-efficient ways for SMEs to reach customers worldwide directly, bypassing traditional barriers such as geographical distance and distribution networks (World Bank Group, 2019).

Furthermore, Industry 4.0 enables SMEs to access global value chains, allowing them to procure inputs more efficiently, reduce production costs, and enhance their competitiveness globally (Kagermann et al., 2013). By leveraging digital technologies, SMEs can expand their operational scope and explore new target markets, driving revenue growth and business expansion. Industry 4.0 technologies such as artificial intelligence (AI) and robotic process automation enable SMEs to streamline operations, minimise costs, and increase productivity. By implementing smart automation systems, IoT devices, and AI-enabled analytics, SMEs can organise production processes more efficiently, improve resource utilisation, and reduce waste (Davenport, 2018).

For example, predictive maintenance systems allow SMEs to identify equipment failures in advance, thereby reducing downtime and maintenance costs (Porter & Heppelmann, 2014). Similarly, AI-driven algorithms can optimise inventory management and supply chains, ensuring the timely delivery of goods while lowering operational expenses (Marr & Ward, 2019). By improving operational efficiency, SMEs can achieve higher production levels and profitability, enabling them to remain competitive in the market for longer periods.

Industry 4.0 fosters a culture of innovation, providing SMEs with opportunities to develop new products and services as well as innovative business models. Advanced technologies such as machine learning, blockchain, and augmented reality support rapid innovation and help SMEs outperform competitors (Bughin et al., 2018). SMEs can leverage

data analytics and customer intelligence to identify emerging trends and market opportunities while encouraging product innovation and customisation (Davenport, 2018). In addition, agile manufacturing techniques promote experimentation and iterative development, thereby reducing innovation-related risks (Porter & Heppelmann, 2014). By embracing Industry 4.0, SMEs can unlock their innovation potential and gain competitive advantages in rapidly changing market conditions.

One of the major drawbacks of Industry 4.0 adoption for SMEs is the potential displacement of jobs due to automation and technological advancement. As repetitive tasks become automated and advanced robotic systems are introduced, there is a risk of reducing the need for manual labour across many occupations (ILO, 2019). This creates a situation in which workforce restructuring and layoffs may become necessary, particularly affecting low-skilled workers who may lack the technical knowledge required to adapt to new technologies. Moreover, the emergence of Industry 4.0 may deepen income inequality and widen socio-economic gaps, as displaced workers may struggle to find alternative employment opportunities (Bughin et al., 2018). SMEs, therefore, need to develop proactive measures, such as employee training and reskilling programs, to successfully transition into the digital environment.

Nevertheless, SMEs continue to face challenges in fully realising the benefits of Industry 4.0 due to limited financial resources, inadequate infrastructure, and a lack of technical expertise (UNIDO, 2019). These challenges hinder SMEs from striving to remain competitive in a digitalised global economy. Accordingly, the research hypothesis is formulated as follows: A lack of financial resources and technical expertise, combined with security challenges, constitutes the primary barrier to SMEs implementing Industry 4.0.

3. Methodology

This study aimed to conduct a literature review in order to examine the challenges and opportunities faced by SMEs in the context of Industry 4.0. The literature review was conducted following the methodological steps outlined below. The objective of the review was to identify the main challenges and opportunities that Industry 4.0 presents to SMEs, and to synthesise existing research on the topic to provide guidance for future studies and practical recommendations for SMEs.

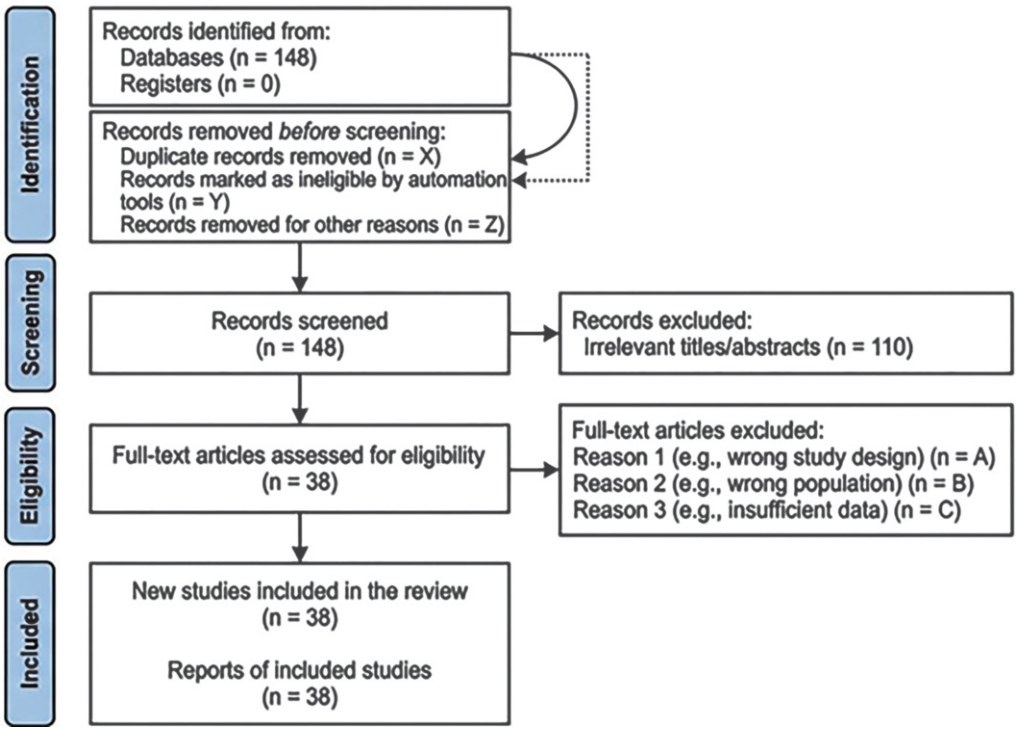
The review included peer-reviewed studies published between 2010 and 2025 in English, German, and Serbian that address the impact of Industry 4.0 on SMEs. Studies focusing exclusively on large companies or on technological aspects of Industry 4.0 without analysing their impact on SMEs were excluded. The literature search was conducted using databases such as Scopus, Web of Science, Google Scholar, and JSTOR, applying keywords including "Industry 4.0," "small and medium-sized enterprises," "SMEs," "challenges," "opportunities," and "digital transformation." Additionally, the reference lists of relevant studies were examined to identify further sources.

To ensure transparency and reproducibility, the literature search was conducted using a combination of keywords and Boolean operators. The primary search string included: ("Industry 4.0" OR "digital transformation" OR "smart manufacturing") AND ("small and medium-sized enterprises" OR "SMEs") AND ("developing countries" OR "emerging economies") AND ("challenges" OR "barriers" OR "opportunities"). The search was adapted slightly across databases to accommodate specific indexing systems while maintaining the same conceptual structure.

The literature review followed a structured, multi-stage process. First, an initial identification phase resulted in 148 records retrieved from selected databases. Second, a screening phase was conducted based on titles and abstracts, excluding studies not directly related to SMEs or Industry 4.0. Third, a full-text eligibility assessment was performed, applying predefined inclusion criteria related to relevance, methodological rigour, and focus on developing countries. Finally, 38 studies were included in the qualitative synthesis. The overall process is summarised in a review flow diagram (Figure 1), ensuring transparency and replicability of the selection procedure.

Figure 1

Literature review selection process



Notes. Created by the authors

To complement the conceptual discussion, the paper includes a descriptive, comparative analysis based on the data collected from the World Bank Enterprise Survey (World Bank, 2026). The dataset reports country-level firm statistics for Bosnia and Herzegovina, Montenegro, Serbia, and North Macedonia, together with a benchmark aggregate for Europe & Central Asia. Indicators are provided for all firms, and, where available, disaggregated by firm size: small (5–19 employees), medium (20–99 employees), and large (100+ employees). Because the data are reported as aggregated statistics rather than firm-level microdata, the empirical component is designed as a benchmarking and gap analysis to describe cross-country patterns and firm-size gradients, without causal attribution.

The empirical strategy proceeds in three steps. First, for each selected indicator, level comparisons are made across countries using the all firms series, and these values are benchmarked against the Europe & Central Asia aggregate. Second, to quantify the firm-size divide, a size-gap measure is computed for each country as the difference between the average outcome for SMEs and the outcome for large firms. Specifically, the SME value is defined as the arithmetic mean of the small-firm and medium-firm statistics, and the size gap is calculated as:

$$Indicator\ Gap\ =\ SME\ average\ -\ Large.$$

Positive values, therefore, indicate that SMEs outperform large firms on a given indicator, while negative values indicate an SME disadvantage. For management capability, the Management Practices Index is only available for medium and large firms. In that case, the reported gap is computed as

$$Indicator\ Gap\ =\ Medium\ -\ Large.$$

Third, the cross-country pattern of size gaps is summarised using a heatmap of standardised gaps. For comparability across indicators measured in different units, gaps are standardised within each indicator using z-standardisation across countries. The heatmap, therefore, highlights where SME disadvantages (or advantages) are most pronounced within each indicator and facilitates the identification of country–indicator combinations that represent the most salient size-related constraints.

The quality of the studies was evaluated using a checklist that included criteria such as clarity of objectives, methodological rigour, presentation of results, and discussion of limitations. All sources were properly cited in order to avoid plagiarism and acknowledge the originality of the authors' work.

4. Research Results

In summary, SMEs in developing countries can gain a wide range of benefits from Industry 4.0, including increased productivity, improved product quality, access to new markets, and greater innovation agility. By adopting digital technologies and leveraging these advantages, SMEs can strengthen their competitiveness, expand their market reach, and achieve sustainable growth in the digital era.

Table 1

Advantages of Industry 4.0 for Small and Medium-Sized Enterprises

Benefit	**Increased Production**	**Improved Products**	**Access to New Markets**	**Innovation Agility**
Achieved through	Lean manufacturing and the use of predictive analytics, artificial intelligence, and the Internet of Things	Additive manufacturing, data analytics, and customer feedback.	E-commerce and global digital platforms	Agile manufacturing strategies, AI-driven consumer behavior analysis, and the promotion of innovation through blockchain, augmented reality, and machine learning.
Authors	Cifone, F.D., Hoberg, K., Holweg, M., & Staudacher, A.P. (2021). 'Lean 4.0': *How digital technologies can support lean practices*?; Davenport, T.H. (2018). *The AI advantage: How to put the artificial intelligence revolution to work.*; Marr, B., & Ward, M. (2019). *Artificial intelligence in practice: How 50 successful companies used AI and machine learning to solve problems.*	Koch, V., Kuge, S., Geissbauer, R., & Schrauf, S. (2014). *Industry 4.0: Opportunities and challenges of the industrial internet.;* Liu, I., Soroka, A., Han, L., Jian, J., & Tang, M. (2020). *Cloud-based big data analytics for customer insight-driven design innovation in SMEs.*	Akpan, I.J., Udoh, E.A.P., & Adebisi, B. (2022). *Small business awareness and adoption of state-of-the-art technologies in emerging and developing markets, and lessons from the COVID-19 pandemic.*; Porter, M.E., & Heppelmann, J.E. (2014). *How smart, connected products are transforming companies.*	Laosirihongthong, T., Samaranaiake, P., & Teh, P.L. (2021). *Key drivers of Industry 4.0 adoption at the firm level: Findings from emerging economies*; Baum, G. (2013*). Innovationen als Basis der nächsten Industrierevolution. In U. Sendler (Ed.),*; Bughin, J., Hazan, E., Lund, S., Dahlström, P., Wiesinger, A., & Subramaniam, A. (2018). *Skill shift: Automation and the future of the workforc;* Kagermann, H., Helbig, J., Hellinger, A., & Wahlster, W. (2013). *Recommendations for implementing the strategic initiative Industrie 4.0: Securing the future of German manufacturing industry.*

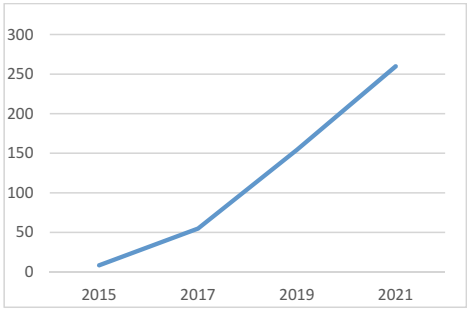
Notes. The table presents the advantages of Industry 4.0 for small and medium-sized enterprises.

Although Industry 4.0 creates a wide range of opportunities for SMEs, it also presents numerous challenges that must be addressed to ensure maximum adoption and benefits. This section examines four major challenges SMEs face in implementing Industry 4.0 technologies and proposes potential solutions.

One of the primary challenges for SMEs in integrating Industry 4.0 is the lack of adequate financial resources to acquire modern technologies and upgrade existing infrastructure. The implementation of Industry 4.0 solutions, such as IoT sensors, AI algorithms, and robotics, requires significant capital investment, which may be unaffordable for many SMEs, particularly those operating in developing countries (UNIDO, 2019). In addition, uncertain returns on investment (ROI) associated with these technologies often discourage SMEs from making appropriate investments. Some countries, such as Jordan, have introduced improved financing mechanisms to support the digital transformation of SMEs, as illustrated in the figure below, which represents a promising development for Industry 4.0 adoption.

Figure 2

Trend of Financing Digital Transformation in Jordanian SMEs



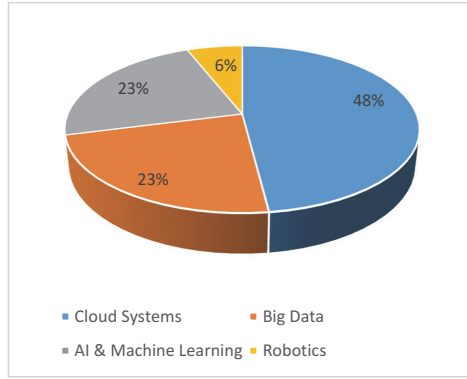
Notes. Created by the authors; adapted from Pellegrino & Abe (2022).

Another major challenge SMEs face in adopting Industry 4.0 is the lack of technical expertise and skilled workers capable of using and managing advanced technologies. SMEs often lack the internal knowledge and resources required to design, implement, and maintain complex digital solutions such as AI systems and data analytics tools (Marr et al., 2018). The rapid pace of technological innovation further complicates SMEs' ability to keep up with emerging trends and develop the skills needed to master new technologies.

In some developing countries, SMEs also face challenges related to insufficient digital infrastructure and connectivity required to access and utilise Industry 4.0 technologies. Limited investment in high-speed internet, unreliable power supply, and outdated telecommunications infrastructure can hinder SMEs' ability to adopt cloud-based solutions, IoT devices, and other digital tools (UNCTAD, 2021). Moreover, rural and remote SMEs may encounter even greater connectivity barriers, significantly widening the digital divide.

Figure 3

Adoption of Different Digital Tools in Small and Medium-Sized Enterprises



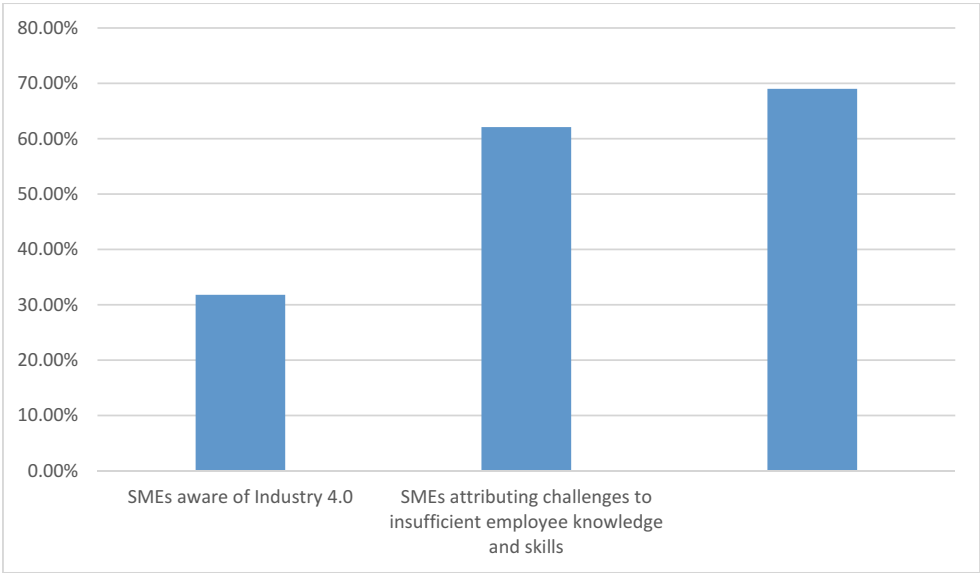
Notes. Created by the authors based on UNCTAD (2021) data.

Based on research by UNCTAD, small and medium-sized enterprises adapt most rapidly to cloud systems among emerging technologies (48%), followed by big data and artificial intelligence (23%), while the smallest share of enterprises has adopted robotics, at only 6%.

In Malaysia, 69% of SMEs were considered ready for Industry 4.0 in 2021. Furthermore, productivity efficiency was expected to increase by 66.4%, despite only 31.8% of SMEs being familiar with Industry 4.0. Additionally, 62.1% of SMEs attributed Industry 4.0 challenges to employees' insufficient understanding of its dynamics (Muhamad et al., 2021).

Figure 4

Readiness of Malaysian Small and Medium-Sized Enterprises to Adapt to Industry 4.0

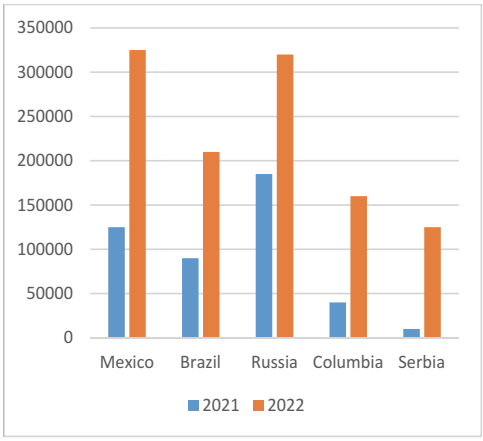


Notes. Created by the authors based on data derived from Muhamad et al. (2021).

The digitalisation of business processes and the growing number of interconnected devices increase SMEs' exposure to cybersecurity threats and data misuse**.** Industry 4.0 technologies, particularly data sharing, connectivity, and interoperability, represent key enablers that simultaneously create opportunities and vulnerabilities through which modern cybercriminals can launch attacks (World Economic Forum, 2019). For example, one study confirmed a significant increase in Trojan-PSW attacks (malicious software attacks designed to steal passwords) targeting SMEs across five countries between 2021 and 2022 (Kaspersky Lab, 2022).

Figure 5

Increase in Trojan-PSW Attacks on Small and Medium-Sized Enterprises in Five Countries Between 2021 and 2022



Notes. Created by the authors based on data derived from Kaspersky Lab (2022).

In addition, SMEs may lack sufficient resources and expertise to implement robust cybersecurity procedures and adequately protect their digital assets. SMEs can be significantly affected by data breaches and cyberattacks, which may result in financial losses, reputational damage, and legal penalties (UNCTAD, 2021). Therefore, SMEs must balance cybersecurity considerations and implement comprehensive measures to prevent risks and protect privacy within the digital environment.

The results of the empirical research using the data from the World Bank Enterprise Survey are given in Tables 1 and 2 and Figure 6. The following section reports the descriptive benchmarking layer based on standardised World Bank Enterprise Surveys indicators for Bosnia and Herzegovina, Serbia, Montenegro, and North Macedonia.

Table 2

Benchmarking Indicators

Indicator	Bosnia and Herzegovina	Montenegro	Serbia	North Macedonia	Europe & Central Asia
Percent of firms having their own web site	87.4	72.8	61.1	79.7	72.7
Average real annual sales growth (%)	3.0	11.0	0.6	6.5	5.3
Average annual employment growth (%)	1.5	1.1	4.2	1.8	4.7
Average real annual labor productivity growth (%)	1.5	9.7	-3.3	4.7	1.0
Percent of firms buying fixed assets	39.5	33.9	38.0	55.5	47.3
Average capacity utilization (%)	81.6	64.4	74.2	70.3	75.8
Average senior management time spent dealing with the requirements of government regulation (%)	9.0	7.9	6.3	5.8	7.9
Average days to obtain an operating license	13.9	13.4	9.7	30.9	37.8
Average days to obtain an import license	28.9	19.1	6.7	9.5	18.9
Average days to receive payment under government contract	29.3	27.7	41.8	59.3	38.7

Notes. Authors' calculation.

Table 3

Gaps Between SMEs and Large Companies

Indicator	Bosnia and Herzegovina	Montenegro	Serbia	North Macedonia	Europe & Central Asia
Percent of firms having their own web site	2.6	-4.25	-30.35		-13.2
Percent of firms buying fixed assets	-12.7	3.05	-29.05		-19.3
Average real annual sales growth (%)	-0.15	-14.3	0.45		-0.25
Average annual employment growth (%)	0.05	-7.6	-0.9		-0.8
Average real annual labor productivity growth (%)	0.1		1.5		1.75
Average capacity utilization (%)	-3.2	-0.5	-10.55		-3.95
Average senior management time spent dealing with the requirements of government regulation (%)	-0.5	3.05	-8.4		-1.25
Average days to obtain an operating license		11.9			-2.75
Average days to obtain an import license	-1.3		-1.8		-0.55
Average days to receive payment under government contract	-0.05	-4.3	0.3		-2.15
Average management practices index (Medium – Large)	-8.0	-18.6	-8.0		-10.1

Notes. Authors' calculation.

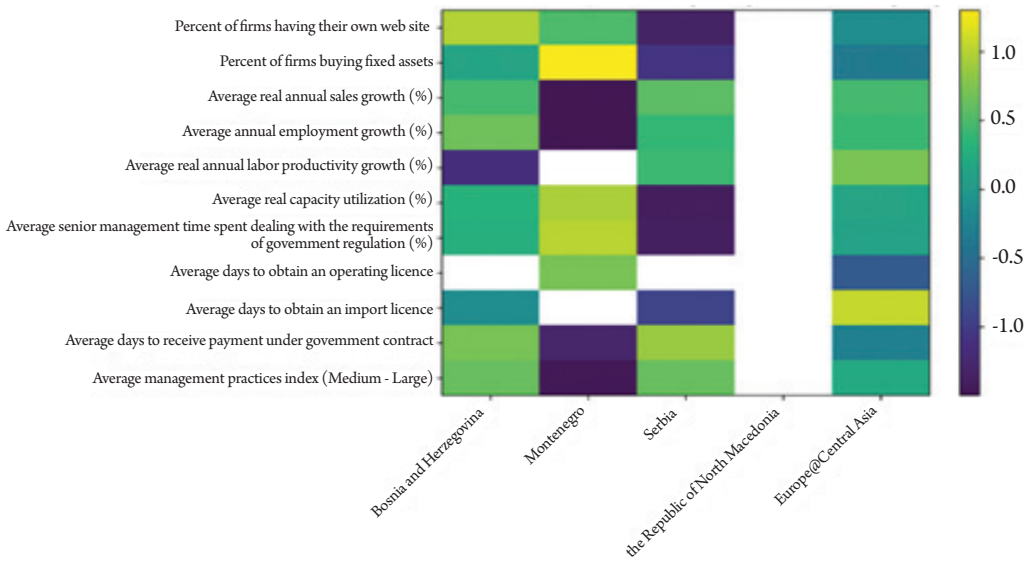
Across the four countries, the indicators point to a clear divide between SMEs and large companies, which is most pronounced in digital presence and investment. In the all-firm benchmark, Bosnia and Herzegovina shows the highest share of firms with a website, while Serbia records the lowest. When size differences are examined, Bosnia and Herzegovina is unusual in that SMEs do not lag large firms in website ownership, whereas Serbia exhibits a very large SME deficit in website adoption, consistent with a strong digitalisation gap by firm size. Fixed-asset investment displays a similarly uneven pattern: SMEs invest substantially less than large firms in Bosnia and Herzegovina and especially in Serbia, while Montenegro shows only a small difference.

Growth indicators are more heterogeneous and do not always mirror adoption gaps. Montenegro's strong aggregate sales and productivity growth are accompanied by large-firm dominance, reflected in negative difference gaps for sales and employment growth. Bosnia and Herzegovina shows relatively small size differentials in sales and employment growth, despite a notable SME shortfall in fixed-asset purchases. Serbia stands out for weak aggregate productivity growth, even though SMEs are not systematically worse than large firms in productivity growth once size gaps are considered, suggesting that broader structural conditions may dominate firm-size differences. Data for SMEs and large companies in North Macedonia were unavailable, hence the missing values in the comparison.

Operational and institutional constraints reinforce the interpretation of uneven upgrading capacity. SMEs tend to operate at lower capacity utilisation where data are available, and the management practices index shows a consistent gradient: large firms score higher than medium firms in every country, indicating that managerial capability is concentrated among larger firms. The heatmap in Figure 6 synthesises these findings by showing that the strongest relative SME disadvantages cluster around digital adoption, fixed-asset investment, and management capability, with Serbia displaying the most pronounced overall size-related constraints.

Figure 6

Gaps Between SMEs and Large Companies



Notes. Authors' calculation.

5. Discussion

The interdependence created by Industry 4.0 enables SMEs to establish collaborative networks and relationships with suppliers, distributors, and other actors within the value chain. By utilising digital platforms and data-sharing mechanisms, SMEs can accelerate procurement processes, improve inventory management, and enhance supply chain visibility (Chauhan et al., 2022). This not only shortens delivery times and reduces production costs but also mitigates supply chain disruption risks, thereby supporting business continuity and customer satisfaction. In line with this argument, the empirical benchmarking highlights that the basic prerequisite for joining digitalised value chains remains uneven across the region. While Bosnia and Herzegovina exhibits very high website prevalence among firms overall, Serbia shows substantially lower overall website adoption, and the size-gap evidence indicates that Serbia's SMEs lag markedly behind large firms on this basic digital marker. This pattern suggests that for a non-trivial share of SMEs, participation in digitally coordinated supply chains may be constrained already at the first stage of digital readiness, before more advanced Industry 4.0 applications become feasible.

Digitalisation and the use of digital tools are becoming increasingly common across companies of all sizes and industries. This trend has brought numerous benefits to firms, including reduced transaction costs and improved communication among employees, suppliers, and business networks. SMEs, in particular, can benefit from digitalisation by integrating into global markets and gaining access to resources such as financing, training, and recruitment channels. Digitalisation also fosters innovation and enables firms to generate and analyse data to improve performance (OECD, 2021). However, the empirical results indicate that digital diffusion is not size-neutral. The heatmap of standardised size gaps shows that the most salient and persistent disadvantages for SMEs are concentrated around digital adoption and upgrading capacity, implying that the digitalisation dividend is likely to be captured disproportionately by larger firms in settings where SMEs exhibit substantial adoption gaps.

Based on the research findings, it can be concluded that Industry 4.0 offers a broad range of advantages for SMEs in developing countries, including increased production, improved products, access to new markets, and greater innovation agility. These benefits are achieved through the adoption of advanced digital technologies, including lean manufacturing, additive manufacturing, e-commerce, artificial intelligence, big data analytics, and blockchain. The empirical evidence suggests that the pathway to these advanced gains is conditional on SMEs' ability to make foundational investments. In Bosnia and Herzegovina and especially Serbia, SMEs are substantially less likely than large firms to purchase fixed assets. Since many Industry 4.0 technologies require complementary investments in equipment, software, and organisational infrastructure, these investment gaps plausibly limit the scale and speed at which SMEs can move from basic digital presence toward more advanced Industry 4.0 solutions.

The study indicates a significant increase in Trojan-PSW attacks targeting SMEs across five countries between 2021 and 2022, confirming the growing cybersecurity risks they face in the digital era. This finding is consistent with studies highlighting the global rise in cyberattacks driven by increasing business digitalisation (Kaspersky Lab, 2022). Research by UNCTAD (2021) also emphasises similar challenges, particularly insufficient digital infrastructure and connectivity in developing countries, which further complicate the implementation of Industry 4.0 technologies. From the perspective of the empirical results, this reinforces a key trade-off. Countries where SMEs are catching up digitally must simultaneously address cybersecurity and resilience, whereas countries with large SME adoption gaps face a dual challenge of accelerating the diffusion of basic tools while ensuring that security capabilities do not lag behind adoption.

The study by Pellegrino & Abe (2022) demonstrates improved financing for SME digital transformation in Jordan, representing a promising development for Industry 4.0 adoption. Similar studies in other countries highlight the need for increased financial support and incentives to enable SMEs to invest in required technologies. For example, Muhamad et al. (2021) report that 69% of SMEs in Malaysia were ready for Industry 4.0 in 2021, although only 31.8% were familiar with its concept, emphasising the importance of education and awareness-raising initiatives. The research further shows that SMEs adopt cloud systems most rapidly, followed by AI and big data an-

alytics, while adoption of robotics remains the lowest. These findings align with other studies indicating similar technology adoption patterns among SMEs (UNCTAD, 2021). One explanation may be the relatively lower cost and easier implementation of cloud solutions compared to robotics technologies. Consistent with the financing argument, the empirical results provide additional indirect evidence that capital constraints are likely to be binding for SME upgrading: in Serbia, SMEs' deficit in fixed-asset purchases is particularly pronounced, indicating that SMEs are less likely to undertake investment steps that typically precede or accompany technology upgrading.

The lack of technical expertise and skilled workers represents another major challenge. Marr et al. (2018) emphasise that SMEs often lack the internal resources and knowledge required to implement and maintain complex digital solutions. This problem is further intensified by the rapid pace of technological innovation, making it difficult for SMEs to keep up with emerging trends. The empirical management-practices gradient reinforces this constraint from an organisational capability perspective: across observed countries and the ECA benchmark, large firms systematically score higher than medium firms on management practices. This suggests that, beyond technical skills, SMEs face a managerial capability gap that can weaken their capacity to effectively absorb and scale digital tools.

Limitations in digital infrastructure and connectivity also pose a significant challenge for SMEs in developing countries. Limited access to high-speed internet, unreliable electricity supply, and outdated telecommunications infrastructure pose major barriers to implementing Industry 4.0 technologies (UNCTAD, 2021). This issue is particularly pronounced in rural areas, where the digital divide further complicates adaptation to new technologies.

Finally, the digitalisation of business processes increases cybersecurity risks. A study by the World Economic Forum (2019) confirms that Industry 4.0 technologies are among the key drivers creating new vulnerabilities. SMEs often lack sufficient resources to implement reliable cybersecurity procedures, making them attractive targets for cyberattacks (UNCTAD, 2021). Given that the empirical evidence points to uneven digital diffusion across firm sizes, cybersecurity policy must be calibrated accordingly. In countries where SMEs are already digitally active, the priority is secure adoption of cybersecurity practices, whereas in countries where SMEs are digitally lagging, cybersecurity capacity-building should be embedded into digital adoption programs early to avoid creating new vulnerabilities during rapid catch-up.

This discussion confirms that, although Industry 4.0 brings numerous benefits to SMEs, several challenges must be overcome to ensure successful integration and the full utilisation of new technologies. Increasing financial support, developing technical expertise, improving digital infrastructure, and strengthening cybersecurity are key steps SMEs need to take. The empirical results sharpen these priorities by indicating that the most consistent and policy-relevant SME disadvantages are concentrated in basic digital presence, fixed-asset investment, and managerial capability. This implies that interventions should be sequenced: foundational digital adoption and managerial practices should be strengthened alongside targeted upgrade financing, rather than focusing immediately on advanced Industry 4.0 technologies that presuppose these prerequisites.

The internet and digital platforms have become essential for SME visibility and for influencing consumer purchasing decisions. In 2016, 45% of SME owners in the United States considered a presence on digital platforms very important for their businesses, while 77% reported that it helped them attract customers (Statista Research Department, 2023). Additionally, 63% believed that digital platform presence could improve their company's image. Nearly 60% of SME owners planned to invest in a new website or improve an existing one, while 45% intended to invest in social media marketing (Statista Research Department, 2023). The empirical comparisons underscore that the digital presence channel is not equally accessible to SMEs across contexts. In some settings, SMEs approach parity with large firms, whereas in others, a large share of SMEs remain without even a basic website. This suggests that the effectiveness of visibility- and platform-based strategies may depend strongly on country-specific diffusion patterns and firm-size constraints.

Social media represents a significant investment for companies, with approximately 97% of Fortune 500 companies maintaining a LinkedIn account, 86% on Twitter, and 84% on Facebook. In addition, 67% operate a YouTube channel, while 36% maintain a

public blog (Statista Research Department, 2023). Social media is also widely used for recruitment purposes, with 92% of U.S. companies and recruiters using it to hire talent in 2015 (Statista Research Department, 2023). LinkedIn is the most commonly used recruitment platform, with 87% of human resources professionals relying on it for hiring. Furthermore, 73% of HR professionals have successfully recruited candidates through LinkedIn, while 39% have optimised their websites for mobile users (Statista Research Department, 2023). From an empirical standpoint, such digital channels are likely to amplify competitive differences when SMEs lag in baseline digital adoption, because firms without a basic digital presence are structurally less able to leverage recruitment platforms, digital marketing, and online customer acquisition.

The internet and digital platforms have become essential to SME visibility and consumer purchasing decisions. In 2016, 45% of SME owners in the United States considered digital presence very important for their business, while 77% stated that it helped attract new customers (Statista Research Department, 2023). Social networks are also extensively used for recruitment, with 92% of U.S. companies and recruiters utilising them for talent acquisition. LinkedIn remains the dominant recruitment platform, used by 87% of HR professionals, while 73% have successfully hired candidates through LinkedIn and 39% have optimised their career websites for mobile users (Statista Research Department, 2023). Given the observed management-capability gradient, the ability to convert digital tools into sustained performance improvements may be constrained not only by access to platforms but also by internal routines for target-setting, monitoring, and incentivising adoption and learning.

To remain competitive, SMEs must prioritise digitalisation and invest in digital tools in order to keep pace with larger firms. Governments can play an important role in facilitating digital adoption by making resources and services available online, promoting digital literacy, and creating incentives for SMEs to invest in digital technologies. By embracing digitalisation, SMEs can benefit from increased productivity, innovation, and improved access to global markets (OECD, 2021). The empirical results imply that incentives for SMEs should be targeted and measurable. In countries where the gaps are largest, policy packages should explicitly aim to close gaps in basic digital presence, upgrading investment, and managerial practices. In practical terms, this suggests combining small grants and vouchers for first-step digitalisation with co-financing for upgrading investments and standardised management training modules.

SMEs can achieve significant advantages through Industry 4.0 adoption. By implementing smart technologies such as the Internet of Things (IoT) and data analytics, SMEs can streamline supply chains, reduce delivery times, and prevent equipment failures. Digital manufacturing technologies, including additive manufacturing, can improve product quality while reducing waste. However, the investment gaps identified empirically suggest that many SMEs may remain at earlier stages of digital transformation, with priority interventions revolving around basic digital visibility, incremental process digitisation, and affordable technologies that do not require substantial fixed-asset commitments.

Access to real-time data represents a key factor for SMEs. By using data analytics tools to process and analyze large volumes of data, SMEs can gain valuable insights into their operations, consumer behavior, and market trends. These insights support critical business decisions, such as identifying areas for process improvement, forecasting demand, and optimizing inventory levels. Predictive maintenance also provides early warnings of equipment failures, enabling proactive measures that prevent costly downtime. The effective use of data and analytics can significantly enhance decision-making and provide SMEs with a competitive advantage. The empirical evidence that SMEs often invest less in fixed assets suggests that the adoption of data-intensive applications may depend on providing SMEs with scalable, lower-capital solutions, combined with training that improves internal capability to use data in routine decision-making.

Industry 4.0 can also enhance customer experience by enabling SMEs to personalise and customise products and services. Smart manufacturing technologies enable the production of customised products in smaller quantities at lower cost. Data analytics helps SMEs better understand consumer behaviour and preferences, allowing them to offer more targeted and relevant products and services. By improving responsiveness to customer needs, reducing delivery

times, and increasing product quality and reliability, SMEs can build stronger customer relationships and improve overall customer satisfaction. For example, SMEs that implemented data management services for storing, organising, and presenting operational, sales, and customer data increased productivity by up to 60%, compared to SMEs relying primarily on e-business and social media initiatives, which increased productivity by approximately 27% and 26%, respectively (Ravindran, 2021). Empirically, contexts in which SMEs are closer to large firms in basic digital adoption are likely to be better positioned to capture these customer-facing benefits, whereas contexts with large adoption gaps may require foundational digitalisation efforts before more advanced personalisation strategies become realistic at scale.

Cost savings represent another significant advantage of Industry 4.0 for SMEs. Smart technologies such as IoT and automation can optimise resource utilisation, reduce operational costs, and improve inventory management. Predictive maintenance helps prevent costly equipment failures and minimises downtime. Digital manufacturing technologies, such as 3D printing, can reduce waste, shorten delivery times, and lower production costs. By adopting Industry 4.0, SMEs can increase profitability and strengthen their market competitiveness. The observed SME deficits in fixed-asset purchases imply that cost-saving technologies requiring capital expenditure may diffuse more slowly among SMEs unless accompanied by dedicated financing instruments specifically designed for upgrading investments.

Industry 4.0 also provides SMEs with access to new markets, enabling them to compete with larger enterprises. Through e-commerce platforms, SMEs can reach a global customer base and expand business opportunities beyond local markets. Industry 4.0 technologies support SMEs in developing new products and services and responding more quickly to changing market demands, helping them gain competitive advantages and expand market share. Rapid technological advancement within Industry 4.0 creates new opportunities for SMEs to differentiate themselves. By adopting emerging technologies such as machine learning, blockchain, and augmented reality, SMEs can develop innovative solutions and new business models aligned with evolving customer needs and market changes (Akpan et al., 2022). Moreover, the modular nature of Industry 4.0 technological platforms enables SMEs to experiment through trial-and-error approaches while minimising innovation risks, fostering a culture of continuous improvement and long-term competitiveness. The empirical management-practices gap implies that even when technology is available, SMEs may struggle to institutionalise experimentation and scaling without improvements in core managerial routines. Therefore, managerial capability building should be treated as a complement to technology diffusion rather than as a separate policy area.

Although challenges remain, such as significant investment costs, cybersecurity risks, and the need for digital literacy, SMEs can overcome these barriers by investing in essential resources, including technology, employee training, and cybersecurity measures. Industry 4.0 represents a valuable investment for SMEs seeking to succeed in today's fast-paced and increasingly digital environment. With strong potential for long-term growth and success, Industry 4.0 offers substantial benefits, including increased efficiency and productivity, improved decision-making, enhanced customer experience, cost savings, and access to new markets. By embracing Industry 4.0, SMEs can strengthen their operations, gain competitive advantages, and unlock new business opportunities. Taken together, the empirical patterns suggest that the constraints for SMEs are context-dependent, but tend to cluster around three prerequisites: baseline digital presence, the ability to finance upgrading investments, and managerial capability. Addressing these prerequisites increases the likelihood that SMEs will capture the downstream productivity and market-access benefits emphasised in the literature.

Linking the findings to the research questions, the combined evidence supports interpreting SME digital transformation in developing countries as a layered stack of constraints, rather than as a set of isolated barriers. Financial constraints shape firms' ability to acquire Industry 4.0 technologies and complementary assets. Skills-related constraints determine whether these technologies can be used effectively and integrated into everyday operations, and governance and managerial constraints influence whether adoption can be sustained, coordinated, and scaled over time. At the same time, the broader policy and institutional environment conditions each of these layers by either easing or reinforcing the underlying bottlenecks

through the quality of infrastructure, access to support instruments, training systems, and regulatory arrangements. This interpretation is consistent with the broader evidence showing that SME digital adoption gaps tend to widen as technologies become more advanced and capability-intensive, implying that successful intervention requires sequencing rather than fragmented support, combining financing, capability development, and infrastructure improvement in a coherent, mutually reinforcing manner.

6. Conclusion and Implications

The Fourth Industrial Revolution is a transformative movement reshaping manufacturing through smart technologies, automation, and data-driven decision-making. While large corporations have rapidly adopted Industry 4.0, SMEs have embraced it more slowly due to perceived barriers such as implementation costs and limited resources. By understanding the specific obstacles SMEs face and adapting policies to address them, governments can foster sustainable economic growth and inclusive development. The empirical benchmarking performed in this study supports this conclusion by showing that differences between SMEs and large firms are visible even at the level of foundational capabilities: in some contexts, SMEs lag substantially behind large firms in basic digital presence and in upgrading-related investment, while a consistent management-capability gradient favours larger firms.

The objective of this study was to examine, through a systematic literature review, the challenges and opportunities that Industry 4.0 presents for SMEs in developing economies. The research method was based on a qualitative analysis of relevant academic and institutional studies published between 2010 and 2023, focusing on identifying recurring themes in technological, financial, organisational, and institutional factors affecting Industry 4.0 adoption. To complement the literature synthesis, the study also provided descriptive empirical evidence for selected economies in the Western Balkans and an ECA benchmark, comparing levels and differences in gaps in digital adoption, investment, performance, operational intensity, regulatory frictions, and management practices.

The main findings indicate that Industry 4.0 offers substantial benefits for SMEs, including increased productivity, improved product quality, enhanced decision-making, access to global markets, and stronger innovation capacity. However, the study also highlights key barriers, including limited financial resources, insufficient technical expertise, inadequate digital infrastructure, and growing cybersecurity risks. The empirical results refine these barriers by identifying where the SME disadvantage is most visible in practice. The strongest and most systematic gaps concentrate in baseline digital presence in some contexts, fixed-asset investment that underpins upgrading, and management capability. Meanwhile, growth outcomes are more heterogeneous, suggesting that macroeconomic conditions and sectoral composition may overshadow firm-size differences in short-run performance.

Industry 4.0, encompassing advanced digital technologies and automation, offers SMEs in developing economies significant opportunities to enhance competitiveness and productivity in global markets. To address existing challenges, governments and stakeholders should raise awareness of Industry 4.0 opportunities and provide SMEs with data-driven guidance on navigating digital transformation. Sharing successful case studies of SMEs that have effectively adopted Industry 4.0 can encourage hesitant firms to follow similar paths. Additionally, governments can support adoption through incentives such as tax relief, subsidies, and regulatory support, enabling SMEs to experiment with new technologies and innovative business models. The empirical evidence implies that such support should be sequenced and targeted. Programs that promote advanced technologies will have limited impact if a large share of SMEs lacks basic digital presence or the capacity to invest. Therefore, effective packages should combine first-step digital adoption support, upgrades to financing instruments, and managerial capability building to strengthen monitoring and target-setting needed for sustained implementation.

6.1. Theoretical Implications

The theoretical contribution of this study lies in providing an integrated overview of the challenges and opportunities of Industry 4.0 adoption among SMEs in developing countries. Unlike many previous

studies that focus primarily on technological aspects or large enterprises, this research emphasises the specific structural constraints faced by SMEs, including financial limitations, lack of technical expertise, infrastructure gaps, and cybersecurity risks. By adding descriptive evidence on the differences between SEMs and large companies, the study also reinforces the view that Industry 4.0 adoption is path-dependent: firm-size differences emerge not only in advanced technologies but also in foundational capabilities that condition subsequent adoption and diffusion. By combining the two approaches, the study moves beyond a purely narrative consolidation of prior findings and connects qualitative insights from the literature with an empirically observable structure of SME–large-firm gaps. This combined design strengthens the practical relevance and external validity of the analysis, particularly for policymakers, development agencies, and SME support institutions seeking evidence-based guidance for digital transformation strategies.

By synthesising existing literature, the study contributes to a clearer understanding of Industry 4.0 as a multidimensional process that combines technological, organisational, and institutional factors. In this way, the research extends existing theoretical discussions by highlighting Industry 4.0's dual role as both an opportunity for competitiveness and a source of new operational challenges for SMEs in developing economies. The observed management-practices gradient supports theoretical accounts that emphasise complementarities between technology and organisational capability: technology diffusion alone is unlikely to generate sustained productivity effects without improvements in internal routines and managerial systems, particularly among non-large firms.

6.2. Policy and Managerial Implications

It is necessary to establish systems through which governments and financial institutions provide SMEs with accessible financing options and resources specifically designed to develop Industry 4.0 capabilities and infrastructure. Public–private partnerships can also play an important role in pooling resources and expertise that support SMEs throughout their digital transformation processes. Policymakers can partially overcome financial barriers by facilitating access to finance and encouraging cooperation among stakeholders, thereby accelerating the adoption of Industry 4.0 technologies among SMEs. The empirical findings indicate that financing should explicitly target upgrading investment, as SMEs in some contexts are substantially less likely than large firms to purchase fixed assets. This supports instruments such as credit guarantees, leasing facilitation, and co-financing schemes tied to digital upgrading plans, with monitoring indicators focused on closing the investment gap between SMEs and large companies over time.

Managers, on the other hand, should recognise the strategic importance of digital technologies and actively invest in tools such as IoT, artificial intelligence, big data analytics, and automation in order to improve operational efficiency and competitiveness. At the same time, continuous investment in employee training and development is essential to ensure the expertise needed to work with new technologies. This also includes recruiting new talent with relevant digital skills. Given the consistent gap in management practices between medium and large firms, managerial interventions should not be limited to technical upskilling. Practical programs focused on target-setting, performance monitoring, and incentive alignment can increase SMEs' "absorptive capacity" and improve the likelihood that digital tools translate into measurable improvements in productivity, capacity utilisation, and market access.

6.3. Research Limitations and Recommendations for Future Research

Industry 4.0 is a relatively new research topic, and much remains unknown about this transformation process. Theoretical frameworks for understanding Industry 4.0 are still evolving. Research on digital transformation is particularly complex due to its multidisciplinary nature, as it involves interactions among technology, society, and organisations. Understanding these interrelationships can be challenging and often requires deeper analytical approaches. As is common among researchers in Bosnia and Herzegovina, data availability is a significant limitation; in this case, data on Industry 4.0 are often limited

or incomplete. An additional limitation of the empirical component is that it relies on aggregated country–size indicators rather than firm-level microdata, thereby restricting inference to descriptive benchmarking and precluding causal identification. Future work should merge firm-level surveys with detailed measures of Industry 4.0 adoption and incorporate sectoral structure and regional infrastructure indicators to explain why size gaps differ across countries.

Schröder (2016) argues that while Industry 4.0 offers numerous opportunities, it also introduces significant requirements, including data security, access to financial resources, the development of implementation approaches, and the availability of skilled employees. Since Industry 4.0 research remains relatively new, theoretical models for its analysis are still under development. Understanding the complex relationships among technological, social, and organisational factors, therefore, requires further investigation. The descriptive evidence presented here motivates future research designs that explicitly examine complementarities.

Future research should focus on developing theoretical frameworks grounded in multidisciplinary approaches and on collecting comprehensive, reliable data through collaboration among industry, government agencies, and academic institutions. Comparative studies across countries and sectors are recommended to identify best practices and key challenges in Industry 4.0 implementation. Additionally, further research could examine SMEs across various industries, conduct in-depth case studies of successful implementations, and analyse impacts on the workforce, cybersecurity, and regulatory and policy influences. Considering broader economic and social impacts, as well as encouraging international research collaboration, may further enhance the understanding and application of Industry 4.0, enabling SMEs to fully benefit from this industrial transformation. In particular, mixed-method designs that combine cross-country benchmarking with targeted SME case studies would help explain the mechanisms behind observed size gaps and translate them into actionable, context-specific policy recommendations.

CRediT authorship contribution statement: Conceptualisation, I. M., M. M. and D. D. M; methodology, I. M., M. M. and D. D. M.; software, I. M., and M. M.; validation, I. M., M. M. and D. D. M.; formal analysis, I. M., and M. M.; investigation, I. M. and M. M.; resources, I. M. and D. D. M.; data curation, I. M. and M. M.; writing—original draft preparation, I.M.; writing—review and editing, I. M., M. M. and D. D. M.; visualisation, I. M. and M. M.; supervision, D. D. M. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement: Data is available upon request.

Funding: This research received no external funding.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

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Изазови и могућности управљања малим и средњим предузећима у земљама у развоју у ери Индустрије 4.0

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***Кључне ријечи**:*
Индустрија 4.0,
мала и средња предузећа,
земље у развоју,
изазови, могућности

JEL класификација:
D02, O17, O43, Q55

САЖЕТАК
Индустрија 4.0 представља трансформациони покрет који доноси значајне промјене у производњи кроз паметне технологије, аутоматизацију и доношење одлука засновано на подацима. Овај рад разматра изазове и могућности са којима се суочавају мала и средња предузећа (МСП) у контексту Индустрије 4.0. МСП могу остварити значајне користи интеграцијом Интернета ствари (IoT), анализе података и других дигиталних алата, што омогућава оптимизацију ланца снабдијевања, смањење трошкова и унапређење управљања залихама. Дигитализација омогућава МСП приступ глобалним тржиштима, подстиче иновације и продуктивност, те побољшава задовољство корисника. Ова студија спроводи систематски преглед литературе с циљем идентификовања главних изазова и могућности које Индустрија 4.0 доноси МСП, као и синтезе постојећих истраживања ради усмјеравања будућих студија и практичних препорука за МСП. Међутим, имплементација Индустрије 4.0 доноси и бројне изазове, укључујући високе инвестиционе трошкове, потребу за обуком радне снаге и ризике у области сајбер безбједности. Владе и финансијске институције могу имати кључну улогу у подршци МСП обезбјеђивањем приступачних опција финансирања и развојем инфраструктуре. Сходно томе, овај рад пружа препоруке владама и финансијским институцијама о томе како боље обликовати пословно окружење за МСП. Препоручују се даља истраживања, са посебним фокусом на развој теоријских оквира, прикупљање поузданих података и спровођење компаративних студија ради идентификовања најбољих пракси и кључних изазова у усвајању Индустрије 4.0.