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REPORT

EXPLORING THE WESTERN BALKANS' READINESS FOR DIGITALIZATION IN MANUFACTURING

Fernando Santiago Rodriguez, Andrea Heredia Zurita, Aleksei Savrasov, Aleksandar Filiposki

SMIC Smart Manufacturing Innovation Centre

REPUBLIC OF SLOVENIA
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SLOVENE ENTERPRISE FUND

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1. Introduction

Digitalization is set to drive the next wave of manufacturing development, while transforming global leadership in innovation and manufacturing across the world. The ability to compete and thrive in this highly competitive environment will depend on firms' and countries' commitments to invest in a set of technological and manufacturing capabilities necessary to enable firms to acquire, master and mobilize advanced digital technologies across production activities and value chains. Public policy is expected to strategically support firms endorsing the ongoing technological revolution by helping them address capability gaps (UNIDO 2019). The caveat, however, is that policymakers often confront the challenge of making decisions without the assistance of tools to objectively appraise the efforts that need to be made and identify where to appropriately allocate resources and target support. The result is bottlenecks to carry out processes of policy experimentation and learning that are required to address the challenge of digitalization in manufacturing.

Digitalization in manufacturing entails integrating a complex mix of innovation, industrial, research and other related policies, which underscores the relevance of multi-stakeholder coordination and collaboration as the foundation for the design and implementation of coevolving innovation and industrial policies (Santiago and Horst, 2018). Still, as discussed elsewhere, while countries at different levels of development are preoccupied with and increasingly integrating digitalization into their industrial development discourse, the power of digitalization as a driver of industrial transformation remains insufficiently exploited (Heredia and Santiago, 2025; Santiago et al., 2025).

Through an application of a methodology developed by UNIDO and GIZ (2024), we explore the case of countries in the Western Balkans. The assessment provides a benchmarking framework to evaluate countries' capabilities for digitalization in manufacturing based on a multidimensional approach of four diagnostic layers:
(i) enabling infrastructure,
(ii) production capabilities,
(iii) innovation capabilities and
(iv) digital capabilities.
The empirical analysis across these four layers of capabilities over the period 2015–2024 renders an overall performance assessment of the region, shedding light on areas policymakers could prioritize to foster digitalization towards advance industrial development.

Section 2 outlines the methodology used for the empirical analysis, which draws on the capability-building framework proposed by Andreoni, Chang and Labrunie (2021), and is further developed in UNIDO and GIZ (2024) and Andreoni et al. (2023). Section 3 presents the key findings from the application, across capabilities, of this methodology to the Western Balkans region. Section 4 concludes with a general overview of the region's top-performing countries in line with their efforts to build foundational capabilities to advance digitalization in manufacturing.

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2. Methodology

UNIDO and GIZ (2024) translate the concept of capabilities developed by Andreoni, Chang and Labrunie (2021) into four layers encompassing 17 quantitative, macro-level indicators as proxies for various capability dimensions that have been identified as essential for advancing digitalization in manufacturing. (**Table 1**). This methodology proposes a Digital Readiness Dashboard (DRD) as a tool to consolidate and graphically organize these indicators into the four layers of capabilities: foundational capabilities (enabling infrastructure, production, and innovation) and digital capabilities. Readiness in this context is understood as a country's ability to tackle both the opportunities and challenges stemming from digitalization in manufacturing (UNIDO and GIZ 2024).

While the indicators for the set of foundational capabilities are derived from a variety of internationally available data sources, the digital capabilities are constructed based on the UN COMTRADE database, using a novel Digital Technologies Classification proposed by UNIDO and GIZ (2024). This classification identifies a comprehensive list of tradable production technologies with digital potential (PTDP), and a subset of products further classified as advanced digital production (ADP) technologies (**Box 1**). Both PTDP and ADP technologies are presented as aggregated values in the DRD.

Box 1. What are PTDPs and ADP technologies?

Production technologies with digital potential (PTDP) encompass a wide range of machine tools and tooling and complementary productive equipment whose coordinated and synchronized operations can be potentially enhanced through forms of digital retrofitting, such as sensorization, automation and network integration.

Advanced digital production (ADP) technologies are multipurpose technology clusters integrating software, hardware and connectivity with applications in various areas of production:

i **R&D, design, pre-manufacturing innovations,** such as the virtualization of the product development stage by using virtual/augmented reality and faster prototyping using 3D printing.

ii **Process innovations,** such as smart production, predictive maintenance and enhanced process and quality control.

iii **Product innovations,** such as smart and connected wearables, household appliances, and vehicles, and highly customized products such as 3D printed clothes or personalized drugs.

iv **Supply-chain management and business model innovations,** enabled by the increased tracking and monitoring of products both upstream and downstream on the production chain, real-time demand and product usage monitoring, and improved decision-making with insights originating from business-related data analytics.

Source: Andreoni and Anzolin (2019), and Andreoni et al. (2021)

Table 1. Dimensions and indicators per capability

Layers of capabilities/ dimensions		Indicators	Description
Enabling infrastructure	Energy	**Energy availability** 1 Electric power consumption	Extensive energy coverage is instrumental for the effective operation of digital machines and equipment.
		Electrical reliability 2 Percentages of firms experiencing outages	Digitalization requires widespread and reliable electricity.
	Digital	**Access to connectivity** 3 Fixed broadband subscriptions	Access to wired broadband Internet connectivity is an enabling factor for digitalization.
		Quality of connectivity 4 Mean download speed (Mbps)	Digital technologies, especially more advanced ones, require high-speed, low-latency and reliable Internet connectivity.
Production	Basic	**Productive investment** 5 Share of manufacturing in total gross fixed capital formation	Proxy for investments made to upgrade the manufacturing structure.
		Productive skills 6 Mean years of schooling	Average number of completed years of education (population ≥25 years).
	Intermediate	**Operational efficiency** 7 ISO 9001 certificates	Firms with good productive and organizational capabilities can obtain the standard certification for quality management.
		Technological absorption 8 Intellectual property rights payments (royalties)	Proxy for firms' level of technological capabilities.
Innovation capabilities	Basic: innovation effort	**Advanced skills** 9 Enrolment ratio in tertiary education	A strong foundation of university-level knowledge is essential for the absorption, diffusion and development of advanced digital technologies.
		Specialized skills 10 Percentage of STEM graduates	Level of specialization of the tertiary education system.
		Research effort 11 Gross expenditure in R&D as a share of GDP	Larger R&D investments indicate capabilities to carry out research and innovation activities.
	Intermediate: innovation outputs	**Research output** 12 Scientific and technical journal articles per million people	Impact on digitalization either directly through research areas or indirectly by creating innovation capabilities.
		Innovation output (patents) 13 Total patents in force per $100 billion GDP	Patents are a common measure for a country's level of innovation capabilities.
		Innovation outputs (property rights) 14 Intellectual property rights receipts	Proxy to measure how technologically advanced a country is (licensing of locally developed technologies to other countries).
Digital capabilities	Absorption and exposure	**Production technologies with digital potential (PTDP)** 15 Imports of production technologies[a] (automation, sensorization and Internet of Things)	Measures engagement with production technologies that have digital potential.
	Deployment and adaptation	**Advanced digital production (ADP) technologies** 16 Imports of ADP technologies[b] (automated and/or with embedded digital systems)	Measures engagement with advanced digital technologies. The aggregated value comprises production technology, parts or components and technology instrumentations.
	Industrial competitiveness	**Competitiveness in ADP technologies** 17 Exports of ADP technologies	It is cautiously assumed that a country's ability to export such products indicates the presence of digital-related capabilities.

Source: Adapted from UNIDO and GIZ (2024).

a) Production technologies with digital potential (PTDP): HS 2017 – Code 84-85, intersected with BEC 4 Code 41 and 42.
b) Advanced digital production technologies (ADP): HS 2017 Code 84-85-90, intersected with BEC 4 Code 41-42.
GDP = gross domestic product; Mbps = megabits per second; R&D = research and development; STEM = science, technology, engineering and mathematics;

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2.1. The Digital Readiness Dashboard (DRD)

The DRD proposed by UNIDO and GIZ (2024) includes 218 countries and is used to calculate global income group averages for each capability indicator. Constructing a framework of capabilities for all countries offers additional advantages, such as the ability to extract regional averages and facilitating comparisons with countries from outside the region under study. Still, the data sources for the different indicators have certain limitations, especially regarding the availability of data by country. For this study, the DRD includes the most recent available data for each country and indicator from the period 2015–2022.[1] In the case of trade data used to compute the most advanced layer of capabilities, data was available up to 2024.

A regional DRD for the Western Balkans was extracted from the global dashboard (**Annex 1**). The analysis will focus on six countries: Albania, Bosnia and Herzegovina, Kosovo*,[2] Montenegro, North Macedonia, and Serbia. Within the defined scope, this report offers a broad overview of countries' readiness for digital transformation in the manufacturing sector, highlighting strengths in foundational capabilities and digital capabilities, while refraining from detailed analysis of individual indicators.

2.2. Criteria for country comparisons

Three criteria were used to compare the overall performance across countries and capabilities within a specific region. These criteria are intended to complement one another, by examining the countries' positions across capabilities, their performance relative to other countries with similar income levels, and the temporal trends of each indicator from 2015–2024.

Criterion 1:
Performance relative to the region
The first criterion identifies the region's top performers across the 17 indicators in the DRD. Each country is positioned relative to others in the region for each indicator, with the best-performing country receiving the highest score per capability. These scores were then aggregated and normalized to a scale of 0–1. This ensures that each capability is given equal weight, which would otherwise not be the case due to the different areas and varying number of indicators covered by each dimension.

Criterion 2:
Performance relative to income level
The second criterion compares a country's average performance to its respective level of development. This is achieved by counting the number of indicators per capability where a country's value exceeds the global average for its respective income group in line with the World Bank's classification system.[3]

Criterion 3: Trends
The third criterion analyses trends across different indicators to identify dynamic country performances across different capabilities. This criterion only considers the number of

1 *Updated in April 2024, covering the years 2015–2022, based on data availability.*
2 *Data availability for Kosovo is limited, which will affect its relative position within the Wester Balkans. Kosovo reported data for seven of the 17 DRD indicators during the period of analysis (less than a half of the full set and none related to digital capabilities).*
3 *World Bank Classification: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups, accessed April 2024.*

** This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence.*

indicators for which a country shows positive change during the period of analysis allowed by the available data (2015–2022). While data coverage is incomplete for certain indicators, limiting the calculation of growth rates, we undertook effort to address missing data by including available data points outside this time frame, where possible.

Table 2 summarizes the three criteria applied in this study. Based on these, a country's overall readiness for digitalization in manufacturing is calculated as the sum of each criterion across all capabilities. This results in theoretically achievable maximum values of 4 for Criterion 1, 17 for Criterion 2 and 16 for Criterion 3.[4]

Section 3 presents the main findings from the analysis carried out for the Western Balkans region across the four dimensions within the DRD and regional criteria.

3. Countries' performances across the DRD: Main findings

The DRD for the Western Balkans evaluates each country's performance across the set of indicators in Table 1. This section first explores each layer of capabilities offering insights into variations in readiness for digitalization in manufacturing across the region. For benchmarking purposes across income groups, the average of the European Union (EU) countries (high-income economies) is included, specifically highlighting Slovenia's performance across indicators.[5] The report then focuses on the cross-country performance of the Western Balkans, applying the set of criteria for regional analysis. Special attention is given to countries that perform well across all three criteria.

3.1. Enabling infrastructure

Different forms of infrastructure sustain efforts towards digitalization, as it provides essential services, such as energy and connectivity, as required for firms to efficiently adopt, adapt and use different forms of digital technologies in manufacturing. Western Balkan countries showed a strong performance in most enabling infrastructure indicators proposed in Table 1. Countries in the region perform above their global income level (upper middle-income) in energy availability, as well as in access to digital connectivity and quality of digital services (Figure 1).

While the region lags behind the European Union average across indicators (Figure 2), most Western Balkans countries are catching up in terms of infrastructure capabilities, relative to countries such as Slovenia. This is illustrated through the comparative performance in the indicators for energy and digital access. However, when it comes to digital services and quality of connectivity, countries such as Serbia, Montenegro and Kosovo* stand out, with performance stronger than Slovenia's. In 2022, Serbia reported the highest mean download speed across the Western

4 *Methodological changes at the source, M-Lab, it is not possible to conduct trend analyses for the indicator on quality of connectivity (mean download speed).*
5 *Slovenia was included as a suitable benchmark for the region, based on a discussion with the project managers.*

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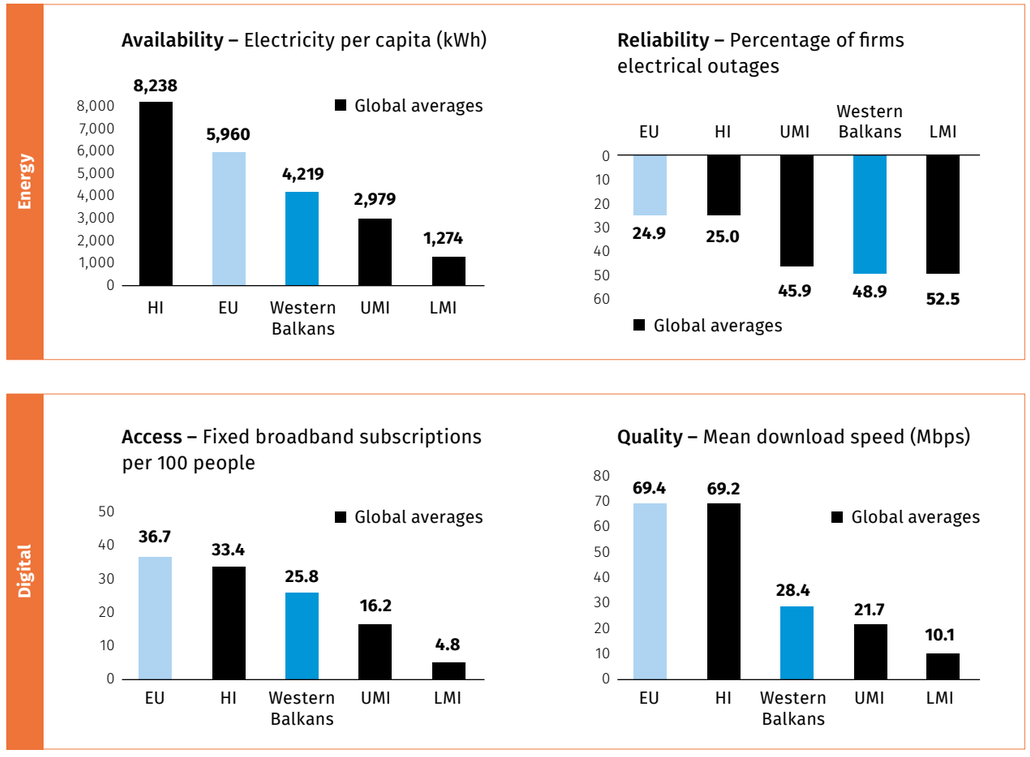
Table 2. Criteria used in the regional comparative analysis

Criteria	Description	Methodology steps	Highest possible score
Criterion 1 (CR1)	Performance relative to the region	▸ Countries were ranked, with the best-performing country receiving the highest score[a] ▸ Scores were aggregated by capability and normalized on a scale from 0–1, with 1 representing the top performer	1.00
Criterion 2 (CR2)	Performance relative to income level	▸ Number of indicators where a country outperforms the global average for its income group	▸ Enabling infrastructure: 4 ▸ Production capabilities: 4 ▸ Innovation capabilities: 6 ▸ Digital capabilities: 3
Criterion 3 (CR3)	Trends	▸ Number of indicators where a country shows a positive trend between 2015–2022[b,c]	▸ Enabling infrastructure: 3 ▸ Production capabilities: 4 ▸ Innovation capabilities: 6 ▸ Digital capabilities: 3
Overall performance by country		▸ Sum was taken of the scores of each criterion across all capabilities	▸ Criterion 1: 4 ▸ Criterion 2: 17 ▸ Criterion 3: 16

Source: UNIDO 2025.

a) The position of a country for each indicator is limited due to lack of data availability;
b) The period 2015–2022 was covered for most indicators. Data was adjusted by taking the latest year available in some cases;
c) Trends are not possible to calculate in one of the 17 indicators (quality of digital infrastructure) due to changes in the methodology to compute the indicator over time.

Figure 1. Western Balkans' performance by income group: Enabling energy and digital infrastructure, 2022



Source: Authors' calculations based on data from https://ourworldindata.org/, https://databank.worldbank.org/source/world-development-indicators, https://www.measurementlab.net/.

Note: kWh = kilowatt hours; Mbps = megabits per second; HI = high income; UMI = upper-middle income; LMI = lower-middle income.

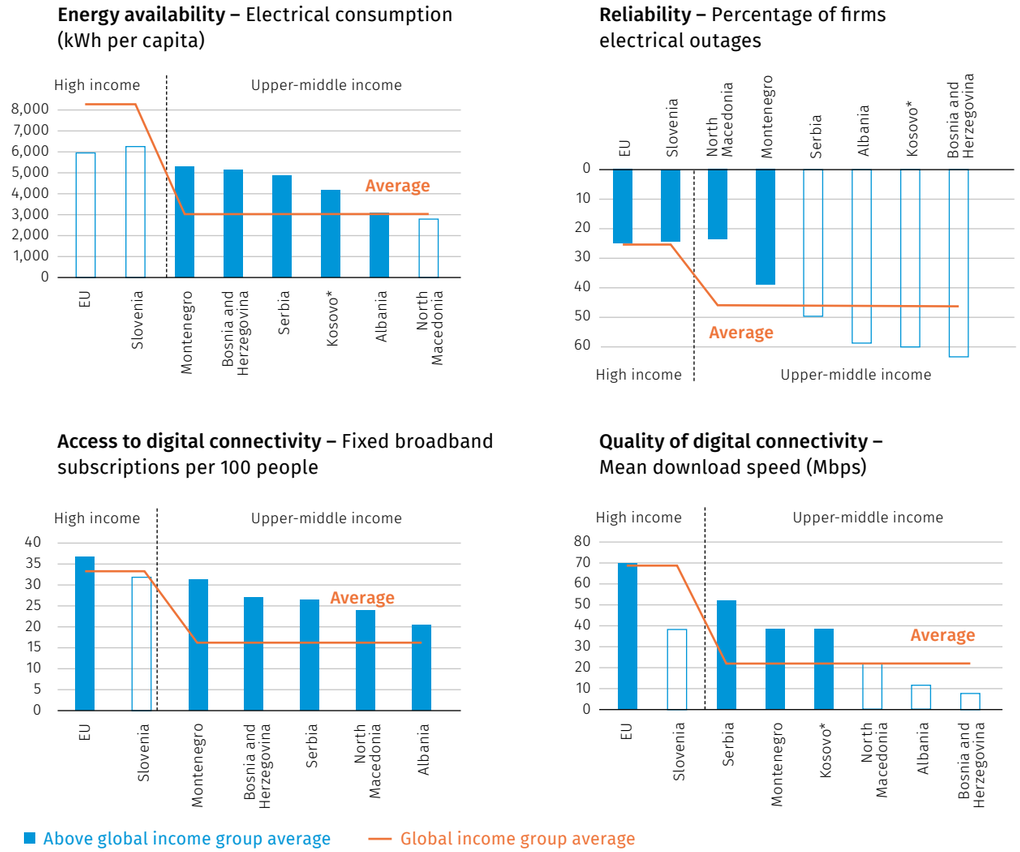
Balkans (51.84 Mbps), well ahead of Slovenia (38.15 Mbps), while Montenegro (38.65 Mbps) and Kosovo* (38.64 Mbps) showed comparable performances to Slovenia.

Countries' performance across the region

The comparative analysis across the region identifies Montenegro as the best performer in enabling infrastructure (Graph 1). The country not only ranks in top positions across indicators but also performs above its income level and demonstrates positive trends in all capability dimensions.

Figure 3 presents the Western Balkans performance relative to the average of upper middle-income economies in the world (Panel A, dark blue) and highlights the positive trends (Panel B, light blue) across indicators over the period 2015–2022. Most countries in the region demonstrate a strong performance in half of the indicators for enabling infrastructure, exceeding the global average for their income level and showing positive trends in both energy and digital access. While Montenegro demonstrates the strongest performance across all four indicators, Serbia leads in terms of quality of connectivity with the highest mean download speed in the region in 2022 (51.84 Mbps), significantly surpassing the average of upper middle-income economies in the world (21.72 Mbps).

Figure 2. Western Balkans and selected country performance across indicators: Enabling infrastructure, 2022

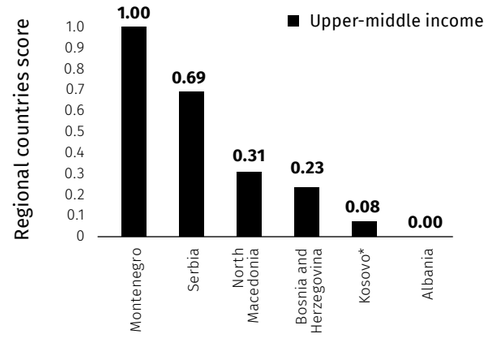


Source: Authors' calculations based on data from https://ourworldindata.org/, https://databank.worldbank.org/source/world-development-indicators, https://www.measurementlab.net/.

Note: The indicator for energy availability relies on data availability. Columns in white indicate that countries do not outperform the global average of their respective income level. kWh = kilowatt hours; Mbps = megabits per second.

Graph 1. Cross-country performance in the Western Balkans: Enabling infrastructure, 2022

Criterion 1. Performance relative to the region – enabling infrastructure

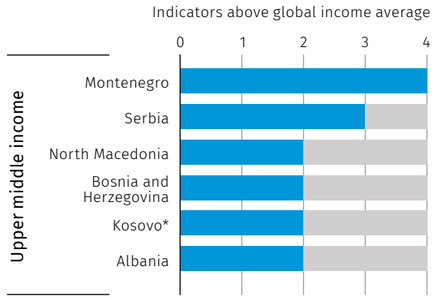


Source: Authors' calculations.

Figure 3. Western Balkans country performance relative to income level, positive trends: Enabling infrastructure, 2015–2022

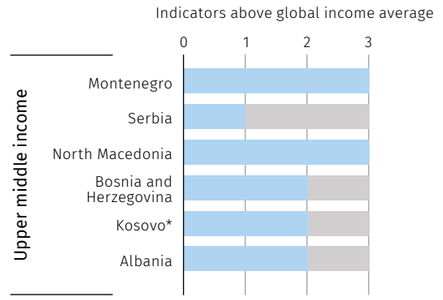
Panel A

Criterion 2. Performance relative to income level

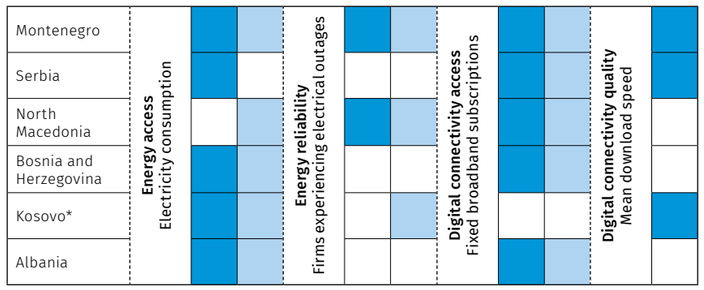


Panel B

Criterion 3. Dynamic performances



Indicators for enabling infrastructure



Note: Trends are not calculated for the indicator of quality of connectivity due to methodological changes at source.

Source: Authors' calculations based on data from https://ourworldindata.org/, https://databank.worldbank.org/source/world-development-indicators, https://www.measurementlab.net/.

3.2. Production capabilities

UNIDO's research documents the path-dependant nature of digitalization in manufacturing (UNIDO 2019). In effect, a country needs to accumulate experience engaging with manufacturing as a necessary condition to make meaningful progress towards digitalization. This is why UNIDO and GIZ (2024) propose, as a second layer of foundational capabilities, those related to the critical role that production capabilities play in engaging with digital production technologies. In this case, a distinction is made between two sets of indicators: (i) basic production capabilities that create the necessary conditions to invest in new technologies, and (ii) intermediate production capabilities which proxy those organizational capabilities that allow for the generation of micro-efficiencies and correct deployment of new digital production technologies (UNIDO and GIZ, 2024).

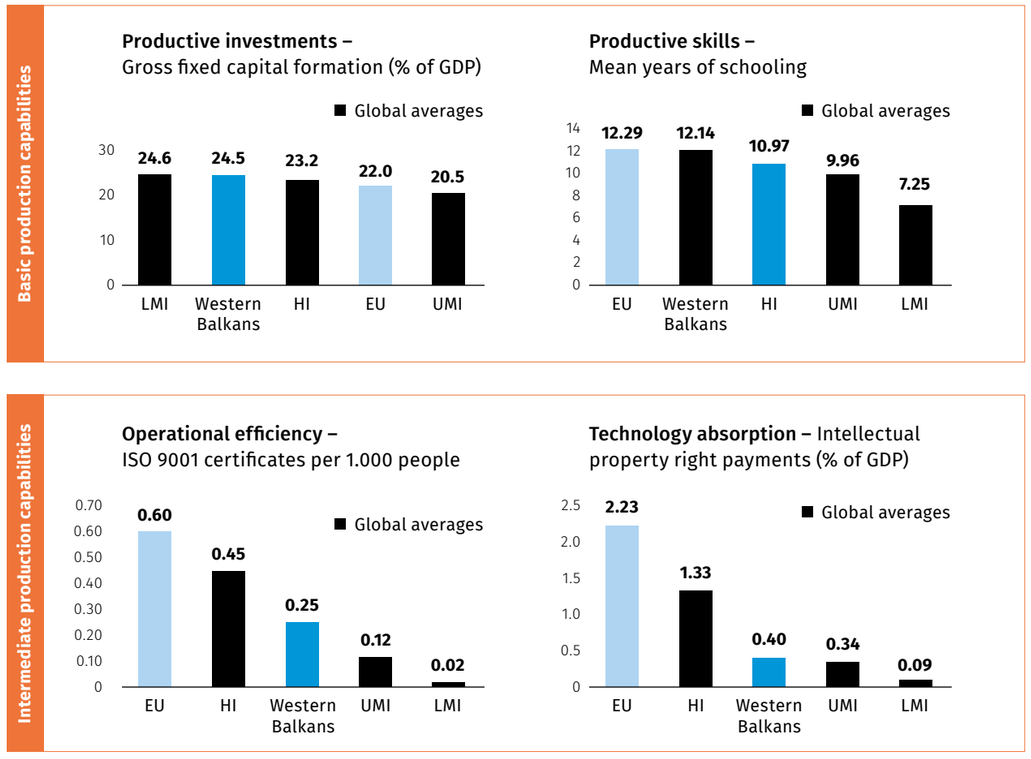
Our findings suggest that Western Balkans countries outperform their global peers in production capabilities, exceeding the average upper middle-income economy across all indicators. The region performs at a comparable EU level in terms of basic production capabilities, even exceeding high-income countries globally in such areas as productive investments, and following closely behind in productive skills. By contrast, the conclusion runs in opposite direction when looking into intermediate production capabilities. There, the Western Balkans lag significantly behind the EU, as illustrated by indicators of operational efficiency and technology absorption (Figure 4).

In addition, compared to Slovenia, the Western Balkans on average are well-positioned in terms of basic production capabilities, while countries such as Serbia and North Macedonia stand out in intermediate production capabilities, outperforming in terms of technology absorption (Figure 5).

Country performance across the region

Among the Western Balkans, Serbia demonstrates the strongest performance in production capabilities (Graph 2). North Macedonia and Montenegro follow, with lower but comparable scores, while Bosnia and Herzegovina and Albania emerge as the lowest-performing countries in the region.

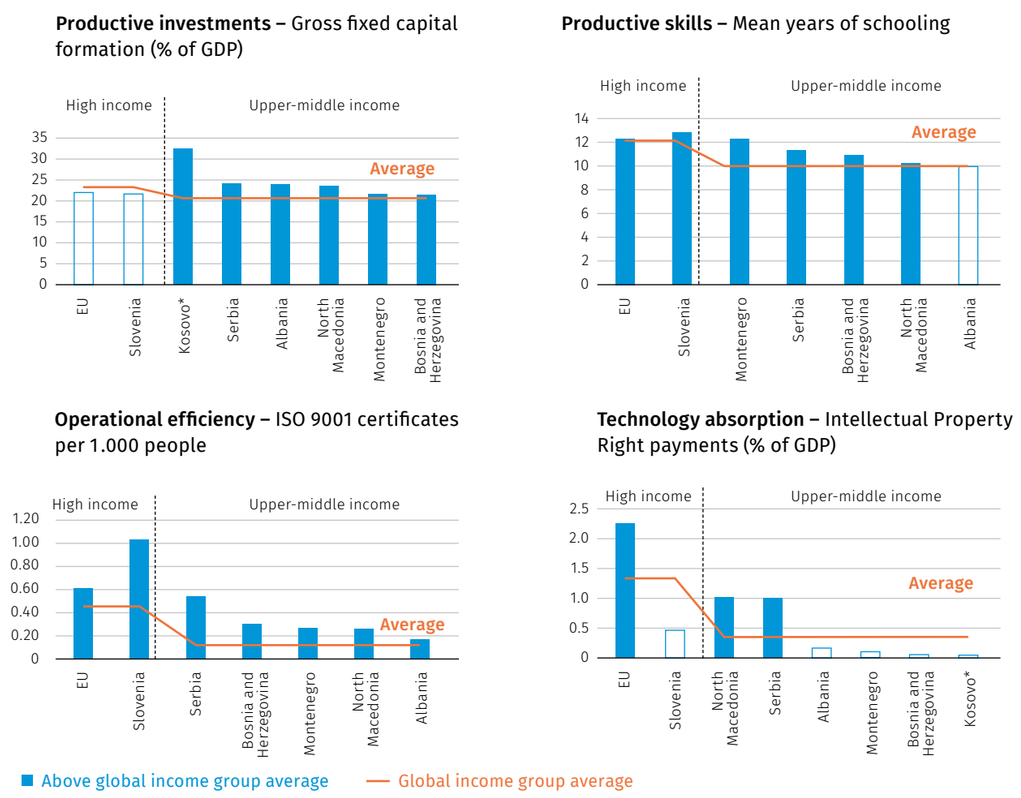
Figure 4. Western Balkans performance by income group: Production capabilities, 2022



Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators, https://uis.unesco.org, https://www.iso.org/the-iso-survey.html.

Note: GDP = gross domestic product; HI = high income; UMI = upper-middle income; LMI = lower-middle income.

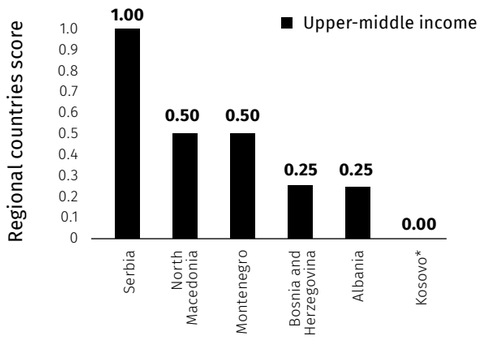
Figure 5. Western Balkans and selected country performance across indicators: Production capabilities, 2022



Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators

Note: Columns in white indicate that countries do not outperform the global average of their respective income level. GDP = gross domestic product.

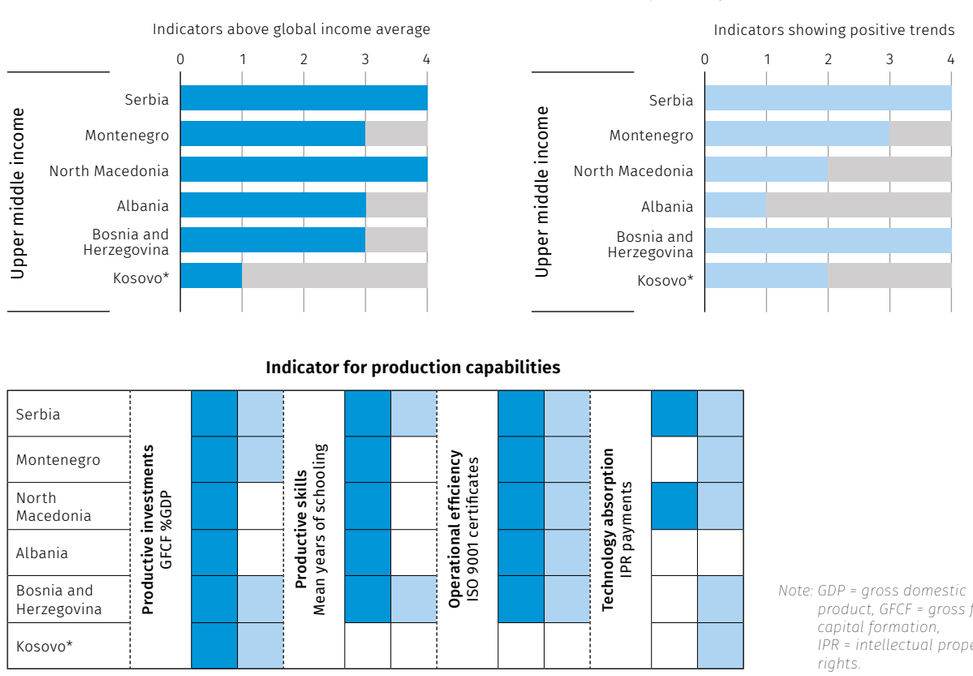
Graph 2. Cross-country performance in the Western Balkans: Production capabilities, 2022



Source: Authors' calculations.

While the Western Balkans are well-positioned in terms of basic production capabilities relative to Slovenia, intra-regional analysis reveals that intermediate production capabilities present the most favourable conditions for catching up compared to the other indicators. All five countries show a dynamic performance in operational efficiency (ISO 9001 certificates per 1,000 people) and technology absorption (payments for intellectual property rights).

Figure 6. Western Balkans country performance relative to income level, positive trends: Production capabilities, 2015–2022



Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators, https://uis.unesco.org, https://www.iso.org/the-iso-survey.html/.

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Figure 6 presents the countries' performance relative to their income level (Panel A, dark blue) and highlights positive trends (Panel B, light blue) across indicators over the period 2015–2022. The Western Balkans, in general, demonstrate a strong performance in production capabilities compared to the average upper middle-income country in the world. Nevertheless, Serbia holds the strongest performance in this dimension, ranking at the top position across all four indicators, while also outperforming its income level and reporting positive trends over the period 2015–2022.

3.3. Innovation capabilities

Mastering digital technologies in manufacturing entails a clear ability to mobilize and derive efficiency and productivity gains, which can be associated with the introduction of those technologies along value chains. As firms gain experience and dexterity, the expectation is that they will become increasingly able to exploit the opportunities that advanced digital production technologies offer to innovate in those technologies. Hence, innovation capabilities provide the core of the third layer of foundational capabilities. Like the case of production capabilities, we observe two main sets of indicators within this layer of innovation capabilities. The first refers to efforts that create the necessary conditions to invest in new technologies and adapt them to local conditions. This is followed by the ability to generate innovations through systematic use of digital technologies.

The analysis indicates that Western Balkans countries are well-positioned in the innovation dimensions compared to their global peers (Figure 7). Within the scope of the basic innovation capabilities, countries in the region perform above average in both advanced and specialized skills and are just slightly behind in terms of research investment efforts.

Compared to the EU, the Western Balkans demonstrate a strong performance in specialized skills (percentage of science, technology, engineering and mathematics [STEM] graduates); in fact, close to the average of high-income economies worldwide.

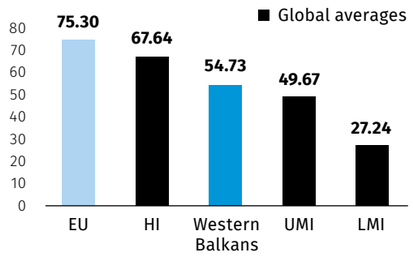
Regarding intermediate innovation capabilities, while the region's performance in research an innovation outputs still lags behind relative to the EU levels, countries hold a greater position than the average upper middle-income economy in terms of publications of scientific and technical articles and receipts for intellectual property rights.

When looking into Slovenia's performance in indicators for innovation capabilities, the country shows a strong performance compared to high-income economies, standing above the global average in all dimensions except for the indicators on innovation outputs (total patents in force and receipts for intellectual property rights). Among the Western Balkans countries, Serbia is the only one with a performance at par with Slovenia, slightly ahead even in specialized skills and surpassing it in receipts for intellectual property rights (Figure 8).

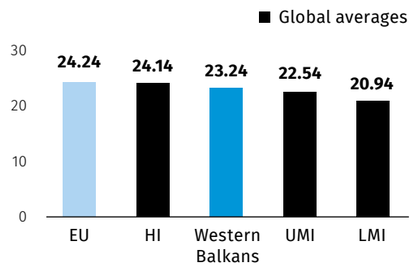
Figure 7. Western Balkans performance by income group: Innovation capabilities, 2022

Basic innovation capabilities

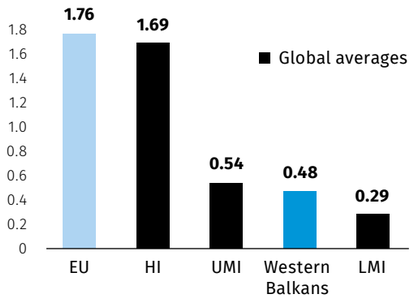
Advanced skills – Gross enrolment ratio in tertiary education



Specialized skills – Percentage of graduates from STEM programmes in tertiary education

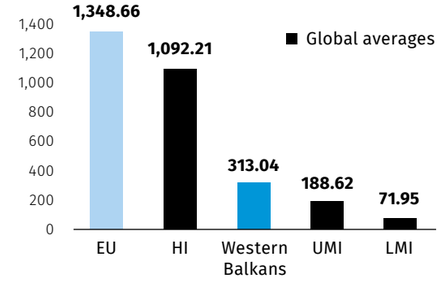


Research effort – Gross expenditure in R&D (% of GDP)

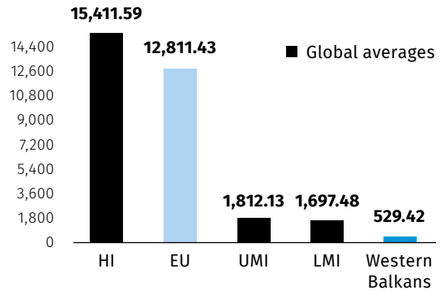


Intermediate innovation capabilities

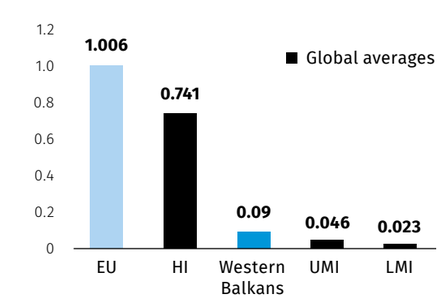
Research output – Scientific and technical journal articles per million people



Innovation output – Total patents in force per $ 100 billion GDP



Innovation output – Intellectual property right receipts (% of GDP)

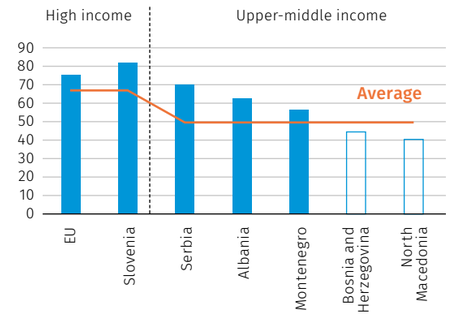


Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators, https://uis.unesco.org, https://www3.wipo.int/ipstats/editIpsSearchForm.htm?tab=patent.

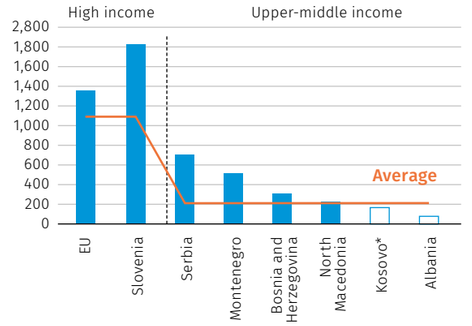
Note: GDP = gross domestic product; R&D = research and development; STEM = science, technology, engineering and mathematics; HI = high income; UMI = upper-middle income; LMI = lower-middle income.

Figure 8. Western Balkans and selected country performance across indicators: Innovation capabilities, 2022

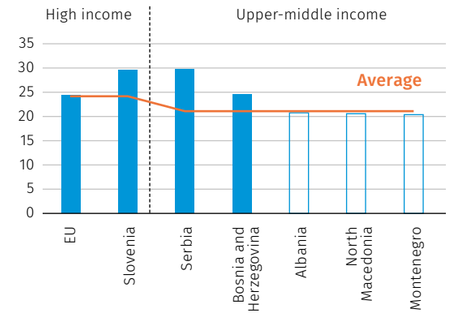
Advanced skills – Gross enrolment ratio in tertiary education



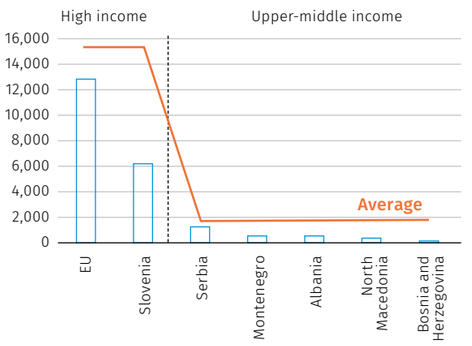
Research output – Scientific and technical journal articles per million people



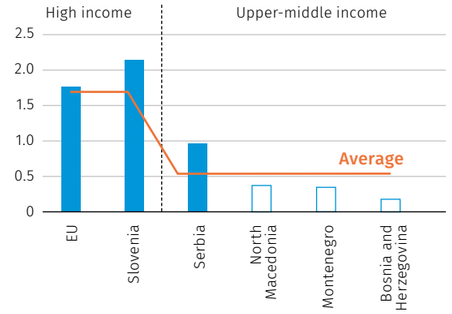
Specialized skills – Percentage of graduates from STEM programmes in tertiary education



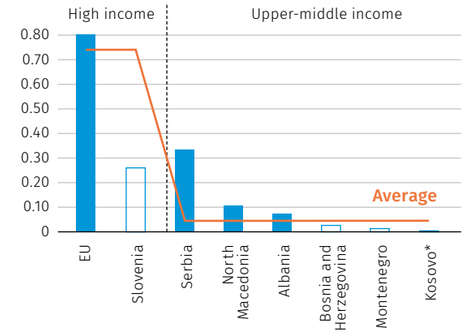
Innovation output – Total patents in force per $100 billion GDP



Research effort – Gross expenditure in R&D (% of GDP)



Innovation output – Intellectual property rights receipts (% of GDP)

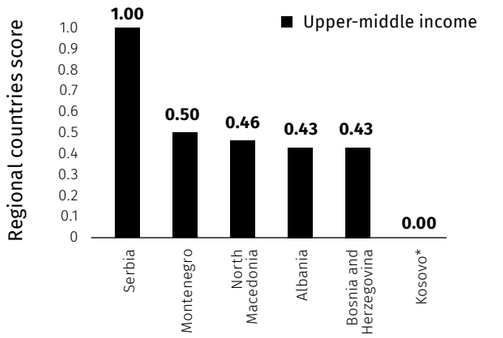


■ Above global income group average — Global income group average

Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators, https://uis.unesco.org, https://www3.wipo.int/ipstats/editIpsSearchForm.htm?tab=patent.

Note: Columns in white indicate that countries do not outperform the global average of their respective income level. GDP = gross domestic product; R&D = research and development; STEM = science, technology, engineering and mathematics.

Graph 3. Cross-country performance in the Western Balkans: Innovation capabilities, 2022



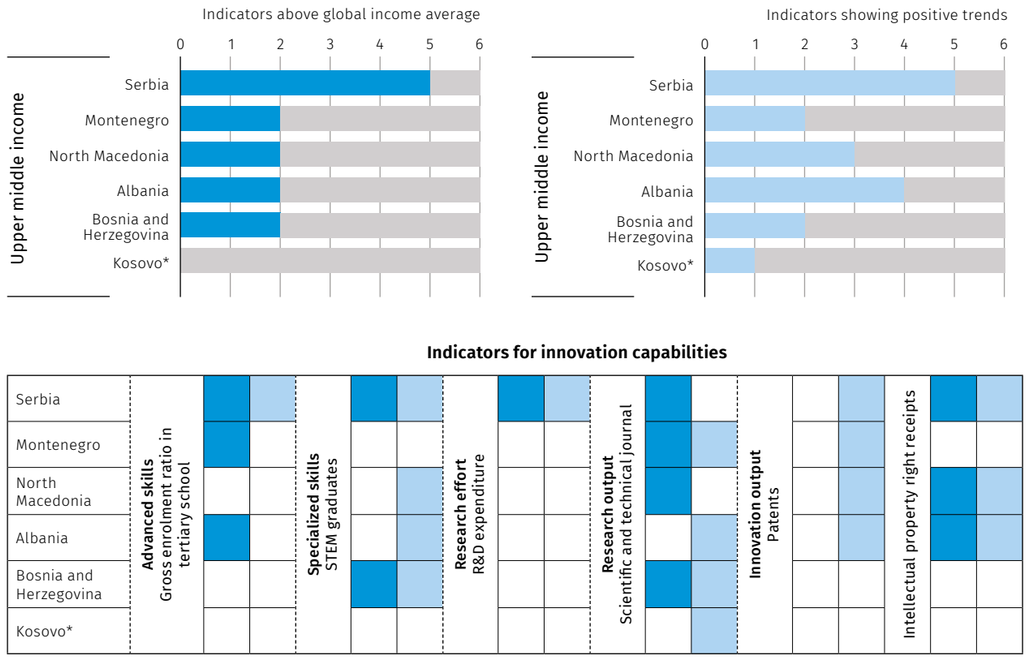
Source: Authors' calculations.

Country performance across the region

Graph 3 presents the cross-country analysis of innovation capabilities across the Western Balkans. Serbia emerges as the region's top performer, holding the highest rankings across all indicators and achieving the top overall score. In contrast, the remaining four countries lag significantly behind, highlighting a pronounced gap within the region.

Figure 9 illustrates countries' performance relative to their income level (Panel A, dark blue) and identifies positive trends (Panel B, light blue) across indicators over the period 2015–2022. Among the six indicators assessed in this layer, most countries in the region perform above upper middle-income economies yet show upward trajectories only in research output, as measured by their scientific and technical publications. The analysis of innovation capabilities reveals a strong dynamism in the Western Balkans. Most countries show positive trends in four of the six indicators. In addition to the dynamic performance in research output, most countries exhibit improvements in specialized skills and both indicators for innovation outputs (total patents in force and receipts for intellectual property rights). Still, Serbia remains the region's front-runner in innovation capabilities. The country ranks highest across all six indicators, and it stands alone in outperforming global peers and improvement in four indicators (advanced and specialized skills, research investment effort, and receipts for intellectual property rights).

Figure 9. Western Balkans country performance relative to income level, positive trends: Innovation capabilities, 2015–2022



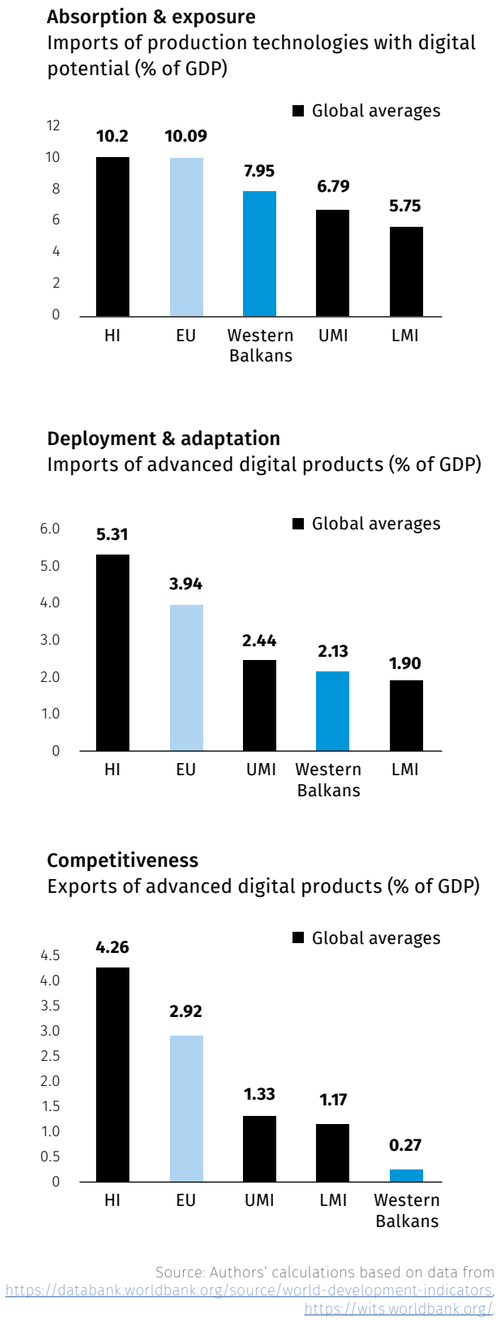
Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators, https://uis.unesco.org, https://www3.wipo.int/ipstats/editIpsSearchForm.htm?tab=patent.

Note: R&D = research and development, STEM = science, technology, engineering and mathematics.

3.4. Digital capabilities

This section's analysis captures countries' engagement with digital technologies. It examines trade levels of targeted manufacturing-related digital products, with a particular focus on ADPs. Figure 10 presents the Western Balkans' performance in digital capabilities compared to global income groups and the EU average. While the region lags behind the EU in digital capabilities, it exhibits favourable conditions compared to their global peers for the absorption and adaptation of digital technologies. Countries in the region outperform the average upper-middle income country in importing PTDPs, while remaining slightly behind in terms of imports of ADP technologies. While further research is necessary to draw conclusions, this finding suggests the stage of capability building and learning through the importation of digital technologies by countries in the Western Balkans. Andreoni and Anzoline (2019) argue

Figure 10. Western Balkans performance by income group: Digital capabilities, 2022

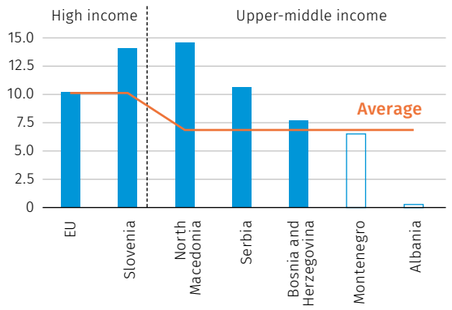


Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators, https://wits.worldbank.org/.

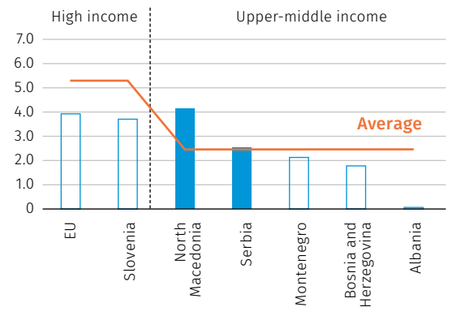
Note: GDP = gross domestic product; HI = high income; UMI = upper-middle income; LMI = lower-middle income.

Figure 11. Western Balkans and selected country performance, across indicators: Digital capabilities, 2022

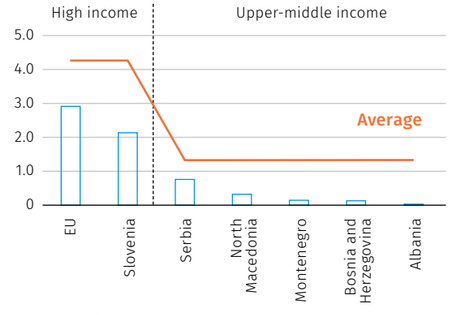
Production technologies with digital potential – imports (% of GDP)



Advanced digital production technologies – imports (% of GDP)



Advanced digital production technologies – exports (% of GDP)



Above global income group average
Global income group average

Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators, https://wits.worldbank.org/.

Note: Columns in white indicate that countries do not outperform the global average of their respective income level. ADP = Advanced digital production; GPD = gross domestic product.

that strategies characteristic of latecomers in this wave of digitalization involve retrofitting and adaptation of existing technologies into digital realms.

Across the three indicators for digital capabilities, Slovenia demonstrates an outstanding performance in technology exposure, with PTDP imports exceeding those of both the EU average and high-income economies worldwide (**Figure 11**). Regarding imports of advanced digital technologies, the country lags slightly behind the EU, while both fall below the average of their global peers. At an individual country level, North Macedonia stands out compared to Slovenia's performance. Already exceeding the global average of the upper middle-income economies both in PTPD and ADP imports, North Macedonia outperforms Slovenia in both indicators. On the other hand, none of the observed countries exhibit a strong performance in the export of advanced digital technologies, indicating challenges in terms of global competitiveness, which remains a latecomer characteristic.

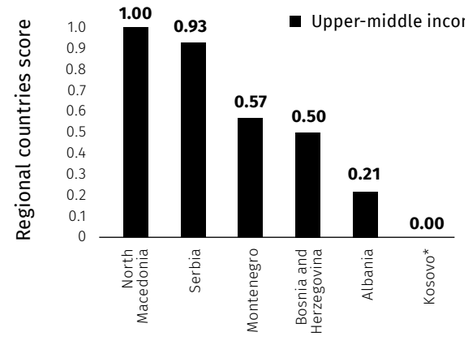
Western Balkans performance across the region

The analysis of trade data to assess Western Balkans countries' engagement with digital production technologies identifies North Macedonia as the top performer in digital capabilities within the region, followed closely by Serbia (**Graph 4**). Both countries hold the highest-ranking positions in imports and exports of digital technologies.

Figure 12 presents countries' performance relative to their income level (Panel A, dark blue), as well as the positive trends (Panel B, light blue) across indicators over the period 2015–2022. Most Western Balkans countries outperform their global peers and show progress in importing PTDPs. Nonetheless, despite these positive conditions for engagement with manufacturing-related digital technologies, only North Macedonia and Serbia hold comparable performances in the more advanced segment of technologies. Both countries lead the region, surpassing their global peers in ADP technology imports and maintaining positive trends over the period of analysis.

Graph 4. Cross-country performance in the Western Balkans: Digital capabilities, 2022

Criterion 1. Performance relative to the region – digital capabilities



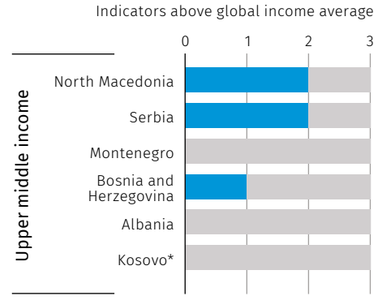
Source: Authors' calculations.

In terms of ADP exports, although countries in the region trail relative to the performance of their income-level peers, progress is evident. Three of the five countries in the analysis record positive trends in this indicator, and Serbia as the most dynamic country in digital capabilities.

Figure 12. Western Balkans country performance relative to income level, positive trends: Digital capabilities

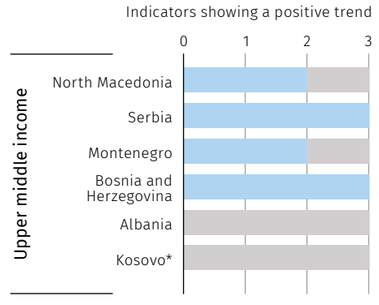
Panel A

Criterion 2. Performance relative to income level

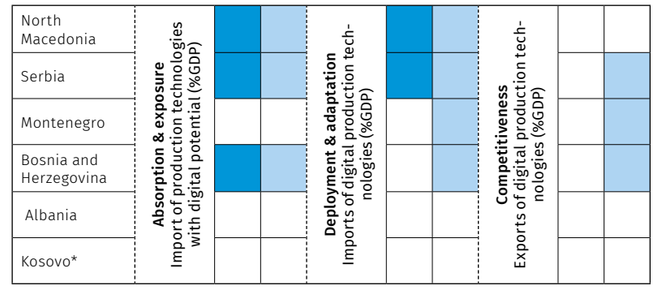


Panel B

Criterion 3. Dynamic performances



Indicators for digital capabilities



Note: GDP = gross domestic product.

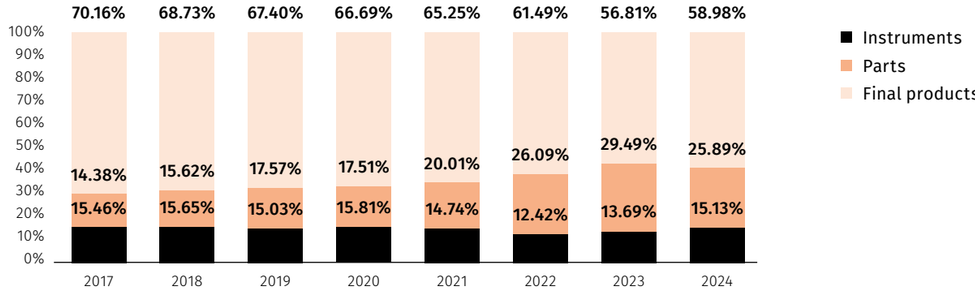
Source: Authors' calculations based on data from https://databank.worldbank.org/source/world-development-indicators, https://wits.worldbank.org/.

3.4.1. Performance in ADP technologies by product category

A more disaggregated analysis of ADP technologies by category of products (instruments, parts and final products) can provide a more detailed overview of countries' performance in digital capabilities. Global imports of ADP technologies in 2024 were led by parts (47.4%), followed by final products (44.2%) and instruments (8.5%). In the Western Balkans, final products were consistently the dominant category of ADP imports over the past several years (Graph 5). In 2024 alone, end-use digital technologies accounted for nearly 60 per cent of the region's total ADP imports, representing the largest share of ADP imports across most countries.

Across the regional landscape, North Macedonia stands out with a broader import composition compared to its peers (Graph 6). In 2024, both parts and final products each accounted for more than 40 per cent of the country's total ADP imports. Aligned with its strong performance in digital capabilities, a diversified ADP imports structure suggests a more advanced level of readiness for digital transformation in manufacturing compared to other countries in the region.

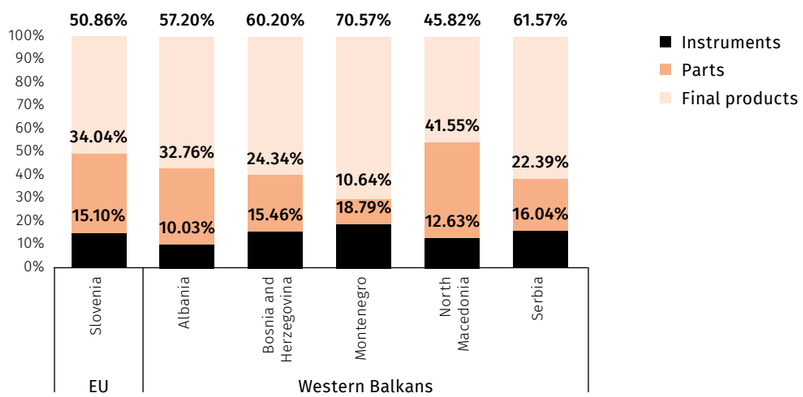
Graph 5. Western Balkans' share of ADP technology imports, by product category, 2017–2024



Source: Authors' calculations.

Note: ADP = advanced digital products.

Graph 6. ADP import structure across the Western Balkans and selected countries, 2024



Source: Authors' calculations.

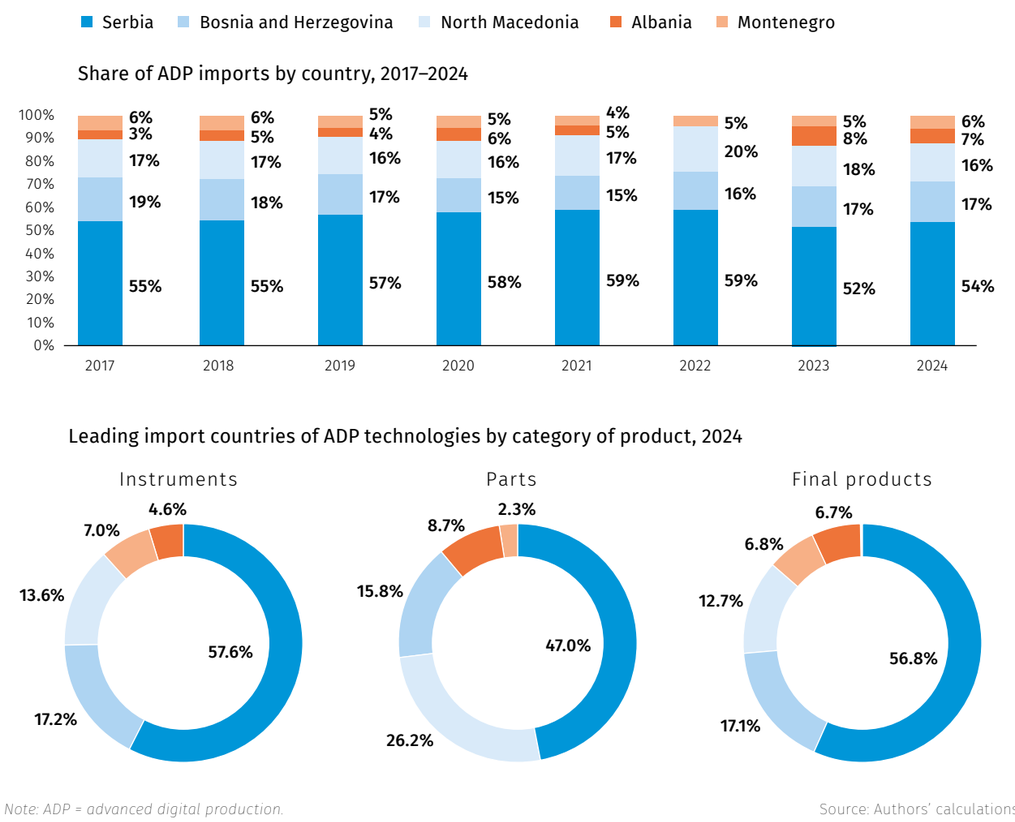
Note: ADP = advanced digital production.

Overall, the ADP import structure of the Western Balkans is comparable to that of Slovenia. In 2024, final products made up 51 per cent of Slovenia's total imports of ADP technologies, representing the leading category, in line with wider EU patterns. Still, parts comprised more than a third (34%) of total ADP imports, indicating a substantial intake of production-related digital components in the country.

Over time, imports of ADP technologies in the Western Balkans have been concentrated in three countries, namely: Serbia, North Macedonia, and Bosnia and Herzegovina (Figure 13). Serbia holds its position as the region's leading importer, consistently accounting for over half of ADP imports across all product categories; yet the remaining portion presents a more varied distribution among other countries. In 2024, Bosnia and Herzegovina ranked second for the imports of ADP instruments (17%), while North Macedonia took the lead in ADP parts (26.2%).

The Western Balkans' export structure of ADP technologies is more evenly distributed across instruments, parts and final products (Graph 7). Serbia plays a central role as the region's principal exporter, accounting for over 80 per cent of total ADP exports across all three product categories throughout 2017–2024.

Figure 13. Leading importers of ADP technologies in the Western Balkans, 2017–2024

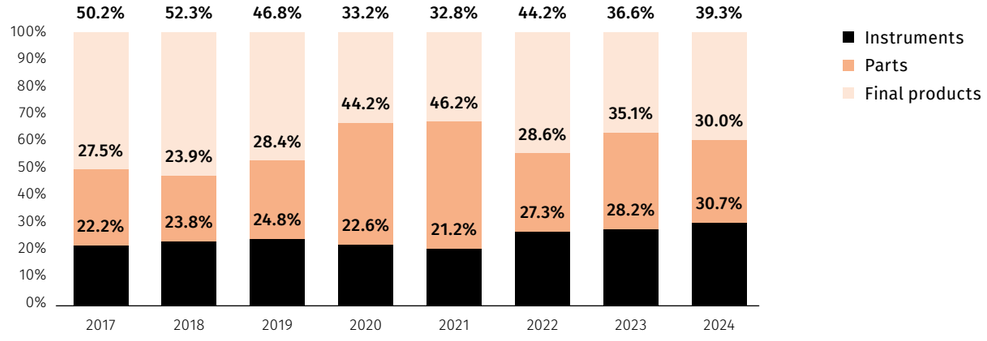


Note: ADP = advanced digital production.

Source: Authors' calculations.

Graph 8 provides a closer look at the composition of ADP exports across countries in 2024. In Serbia, final products make up for the largest share (40.4%), yet instruments and parts represent, each, a third of the country's total ADP exports. ADP exports in Bosnia and Herzegovina's primarly consist of instruments (48%), while parts dominate North Macedonia's structure (44.3%) and final products lead in Montenegro (50.2%). By comparison, Slovenia's ADP exports structure leaned towards final products (40.4%), with instruments following closely behind (39.2%).

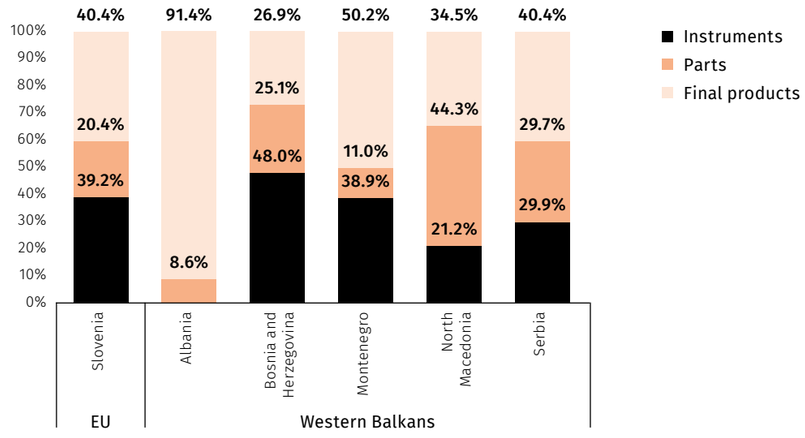
Graph 7. Western Balkans' share of exports of ADP technologies, by product category, 2017–2024



Source: Authors' calculations.

Note: ADP = advanced digital products.

Graph 8. ADP exports structure across the Western Balkans and selected countries, 2024



Source: Authors' calculations.

Note: ADP = advanced digital production.

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4. Summary of results: A multidimensional view on digital readiness capabilities

The results of the diagnostic framework provide an overall performance assessment, highlighting that readiness to engage and adopt digital transformation for industrial development depends on countries' strengths across all four capability layers:
(i) enabling infrastructure,
(ii) production capabilities,
(iii) innovation capabilities and
(iv) digital capabilities.
The analysis examines the Western Balkans performance over the period 2015–2022.
This section presents a general overview of the findings, with insights into the region's top-performing countries.

Countries' overall performance

Building on the regional performance criteria introduced in the analysis, we identify countries' performance across DRD dimensions. Table 3 presents a summary of the results by country, highlighting their relative performance in the region (first criterion), the number of indicators in which they achieve the best performance based on income level (second criterion), and the number of indicators showing a positive trajectory over the period 2015–2022 (third criterion).

Countries are ranked based on the first criterion, which captures their overall comparative performance within the region. Serbia stands out as the Western Balkans frontrunner, not only leading across several foundational capability dimensions, but also showing the highest number of indicators that both exceed the global averages of upper middle-income and demonstrate positive performance

Table 3. Western Balkan countries' performance across the Digital Readiness Dashboard

Rank C1	Country	Income group	Performance relative to the region C1: Capabilities, total score	Performance relative to income level C2: Number of indicators above average/17	Positive trends C3: Number of indicator with a positive trend/16
1	Serbia	UMI	3.62	14	13
2	Montenegro	UMI	2.57	9	10
3	North Macedonia	UMI	2.27	10	10
4	Bosnia and Herzegovina	UMI	1.41	8	11
5	Albania	UMI	0.89	7	7
6	Kosovo*	UMI	0.08	3	5

Source: Authors' calculations.

Note: For visualization purposes, the higher scores of the first criterion and the second and third criteria's highest number of indicators are represented by the darkest shade of yellow; UMI = upper-middle income.

trends. Nevertheless, a closer examination of the DRD paints a comprehensive picture of where all countries stand against their regional context across the four layers of capabilities.

While Serbia holds the top score in the region for production and innovation capabilities, countries such as Montenegro and North Macedonia show the strongest performance in enabling infrastructure and digital capabilities, respectively. **Figure 14** summarizes the results for all six countries disaggregated by capability. Panel A presents the countries' individual scores for each capability, while Panels B and C illustrate the number of indicators where countries outperform the average of their income group and where they show improvements, respectively.

Serbia is the strongest performer in the Western Balkans, holding the highest regional scores in production and innovation capabilities, while ranking second both in infrastructure and digital capabilities. The country outperforms its global peers in 14 indicators and demonstrates progress in 13 indicators across the dashboard. Despite Serbia's well-established status, performances by Montenegro and North Macedonia are also worth noticing. Montenegro is the single country in the region to demonstrate a strong performance in all four indicators for enabling infrastructure, both in terms of income level and progress over the period 2015–2022. Across the other capabilities, similar strength is only observed in half of the indicators of production capabilities (productive investments and operational efficiency) and one indicator in the innovation capabilities (research output). Although Serbia falls behind the regional score in enabling infrastructure, it stands out for its performance in terms of the quality of Internet connectivity. Serbia held the highest mean download speed of the region in 2022 (51.84 Mbps), significantly exceeding the average of the upper middle-income economies in the world (21.72 Mbps).

By contrast, North Macedonia emerged as the leader in digital capabilities, surpassing the global average of upper middle-income economies and reflecting improvement in the import indicators used in the analysis. The country's dynamic performance in digital capabilities points to its increasing engagement with PTDPs and a growing capacity to implement more ADP technologies. Though Serbia ranks a close second in this dimension, it stands out for its dynamism in all indicators, covering both imports as well as exports. Nevertheless, while Serbia's trade in advanced digital production technologies is heavily concentrated in end-use products, North Macedonia reveals a different structure throughout the period, with parts representing the largest share of ADP exports and over a third of ADP imports.

While North Macedonia's performance in digital capabilities suggests a high level of readiness, it lags behind in foundational capabilities, revealing critical areas for improvement. Across the foundational capabilities, the country shows strong performances relative to income level and improvement trends in five out of the 14 indicators: half the indicators in enabling infrastructure (energy reliability and digital connectivity access), both indicators for intermediate production capabilities (operational efficiency and technology absorption), and one indicator in innovation capabilities (innovation output, measured by receipts for intellectual property rights).

Despite the observed positive dynamics in the Western Balkans regions over the study period, the findings from the analysis also suggest a relative widening gap vis-à-vis the aggregate EU performance, particularly in

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Figure 14. Best performances in the Western Balkans across capabilities

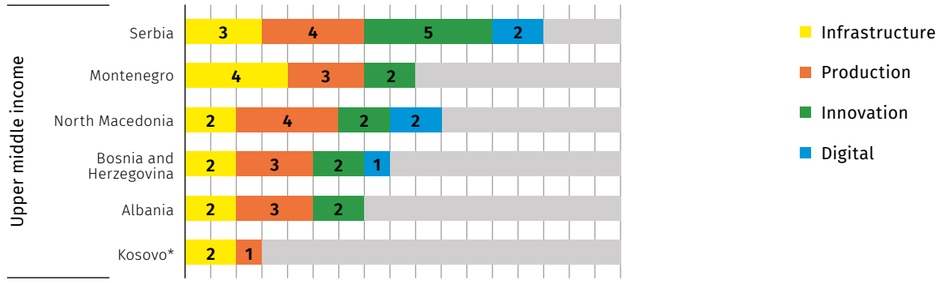
Panel A

Criterion 1. Performance relative to the region

Country	Enabling Infrastructure	Production capabilities	Innovation capabilities	Digital capabilities	Total score
Serbia	0.69	1.00	1.00	0.93	**3.62**
Montenegro	1.00	0.50	0.50	0.57	**2.57**
North Macedonia	0.31	0.50	0.46	1.00	**2.27**
Bosnia and Herzegovina	0.23	0.25	0.43	0.50	**1.41**
Albania	0.00	0.25	0.43	0.21	**0.89**
Kosovo*	0.08	0.00	0,00	0,00	**0.08**

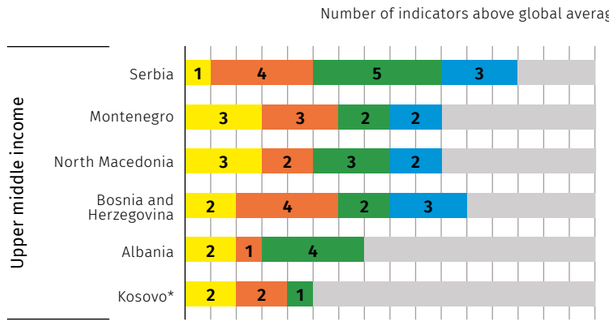
Panel B

Criterion 2. Performance relative to income level



Panel C

Criterion 3. Dynamic performance



Source: Authors' calculations.

Note: Countries are ranked by their total score. For visualization purposes, the highest scores for criterion 1 are highlighted in the capability's respective colour.

advanced stages of accumulation of foundational capabilities. Innovation remains a key bottleneck for catching up in an increasingly digital world. This finding illustrates one of the most relevant challenges introduced by digitalization in manufacturing. Countries often need to accelerate progress chasing a moving target relative to more advanced industrial economies. The opportunity, but also the challenge, is for laggard countries to reorient strategic decisions to foster industrial development by searching new pathways for catching up through upgrading and modernization, with advanced digital technologies at the core (UNIDO, 2019). Leapfrogging in this context of deepening of digitalization necessarily involves improvements in the functioning of innovation systems to accelerate technological adoption, while advancing participatory approaches to policymaking to leverage complementary resources from different agents and actors underpinning industrial innovation and digitalization in manufacturing (Santiago and Horst, 2018).

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Annex

Annex 1. Readiness for digitalization of manufacturing, Digital Readiness Dashboard (DRD) results for the Western Balkans

			Foundational Capabilities																	
		Layer	Enabling Infrastructure				Production capabilities				Innovation capabilities						Digital Capabilities			
			Energy		Digital		Basic		Intermediate		Basic (effort)			Intermediate (output)			Absorption & exposure	Digital capabilities Deployment & adaptation	Competitiveness	
		Dimensions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
			Energy availability	Energy reliability	Access to digital connectivity	Quality of connectivity	Productive investments	Productive skills	Operational efficiency	Technology absorption	Advanced skills	Specialised skills	Research effort	Research output	Innovation output (patents)	Innovation output (royalties)	Absorption and exposure to production technologies with digital potential	Deployment and adaptation of digital production technologies	Industrial competitiveness in digital technologies	
		Indicators	Electricity consumption per capita	Percentage of firms experiencing electrical outages	Fixed broadband subscriptions per 100 people	Mean download speed (Mbps)	GFCF (% of GDP)	Mean years of schooling	ISO 9001 certificates	Intellectual Property Right payments (royalties) (% of GDP)	Gross enrolment ratio in tertiary education	Percentage of graduates from STEM programmes in tertiary education	Gross Expenditure in R&D (% of GDP)	Scientific and technical journal articles per million people	Total patents in force per 100 bi USD GDP	Intellectual Property Right receipts (royalties) (% of GDP)	Imports of production technologies (% of GDP)	Imports of digital products (% of GDP)	Exports of digital products (% of GDP)	
		Years	2015-2022	2015-2022	2015-2022	2022	2015-2022	2015-2022	2015-2022	2015-2022	2015-2022	2015-2022	2015-2022	2015-2020	2015-2022	2015-2022	2017-2022	2017-2022	2017-2022	
Economy	**Subregion**	**Income group**																		
Albania	Western Balkan	Upper middle income	3,138.67	58.70	20.48	11.47	23.89	9.98	0.1627	0.168	62.73	20.81		58.90	496.924	0.06990	0.360	0.065	0.001	
Bosnia and Herzegovina	Western Balkan	Upper middle income	5,118.25	63.40	27.08	8.16	21.40	10.97	0.2966	0.064	44.63	24.52	0.19	281.01	122.580	0.02711	7.695	1.771	0.136	
North Macedonia	Western Balkan	Upper middle income	2,732.13	23.20	24.19	21.59	23.46	10.23	0.2537	1.015	40.55	20.61	0.38	206.19	317.036	0.10118	14.529	4.155	0.319	
Montenegro	Western Balkan	Upper middle income	5,278.42	38.70	31.26	38.65	21.51	12.31	0.2592	0.106	56.07	20.45	0.36	497.85	497.608	0.01474	6.578	2.132	0.136	
Serbia	Western Balkan	Upper middle income	4,881.35	49.50	26.19	51.84	24.16	11.37	0.5313	1.007	69.69	29.82	0.97	687.24	1212.962	0.33148	10.573	2.534	0.759	
Kosovo	Western Balkan	Upper middle income	4,163.35	59.90		38.64	32.36		0.0000	0.047				147.06		0.00285				

Source: Authors' calculations based on https://ourworldindata.org/, https://databank.worldbank.org/source/world-development-indicators, https://www.measurementlab.net/, https://uis.unesco.org, https://www.iso.org/the-iso-survey.html, https://www3.wipo.int/ipstats/editIpsSearchForm.htm?tab=patent, https://wits.worldbank.org/.

Note: data taken from global DRD for the period 2015–2022.
GDP = gross domestic product; GFCF = gross fixed capital formation; R&D = research and development; Mbps = megabits per second; STEM = science technology, engineering and medicine.

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