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From Foundations to Frontiers: Digital Readiness for Manufacturing in the Western Balkans

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Abstract

As digital technologies reshape global manufacturing competitiveness, countries in the Western Balkans face both significant opportunities and strategic challenges in the evolving industrial landscape. This brief assesses the region's readiness for digital transformation in manufacturing over 2015–2024, using the UNIDO-GIZ Digital Readiness Dashboard (DRD). The analysis reveals a heterogeneous region: while most economies demonstrate solid performance in enabling infrastructure and production capabilities, gaps persist in innovation systems and in the adoption of advanced digital production (ADP) technologies. Closing these capability gaps requires coordinated policies to strengthen infrastructure, innovation ecosystems and ADP engagement, while fostering regional cooperation to support more inclusive digital industrialization.

Key Messages

- 1.** Western Balkan economies demonstrate solid foundations in enabling infrastructure and production capabilities relative to their income-group peers, but innovation gaps and uneven ADP engagement constrain the translation of these assets into industrial competitiveness.
- 2.** Intra-regional heterogeneity is substantial: Serbia leads in production and innovation capabilities, Montenegro in enabling infrastructure, and North Macedonia in digital capabilities.
- 3.** Realizing the potential of Industry 4.0 in the Western Balkans requires coordinated national and regional action to strengthen innovation ecosystems, accelerate ADP adoption, close skills gaps, and leverage EU integration to drive industrial upgrading.

Introduction¹

The rapid rise of artificial intelligence (AI) and the digitalization of production systems is a defining megatrend of contemporary industrial development. Advanced digital production (ADP) technologies,² including the Internet of Things (IoT), big data analytics, advanced robotics, cloud computing and additive manufacturing are transforming manufacturing processes, enhancing efficiency, adaptability and real-time decision-making across value chains. Countries and firms that successfully adopt, adapt and deploy these technologies can gain substantial competitive advantages, while those that fail to do so risk exclusion from higher value-added segments of global value chains (GVCs).

Readiness for digital transformation in manufacturing extends well beyond digital infrastructure and connectivity. It depends on a comprehensive and cumulative set of capabilities that enable countries to absorb digital technologies, tailor them to local industrial needs and effectively apply them

across manufacturing processes. Over the past decade, countries in the Western Balkans³ have made meaningful progress in digitalization, particularly in expanding digital connectivity and energy infrastructure. Many now outperform global peers within their income groups in terms of access and quality of connectivity.

Yet, with some exceptions, the region has not fully leveraged digitalization to advance industrial development and manufacturing competitiveness. Connectivity is a necessary but insufficient condition for competitiveness: productivity and export gains materialize when firms combine it with complementary production capabilities, workforce skills, and innovation systems that enable the adoption, adaptation and diffusion of ADP technologies. Without these foundations, digital progress remains largely confined to access and consumption, while industrial upgrading stalls and capability gaps widen.

This brief⁴ applies the UNIDO-GIZ Digital Readiness Dashboard (DRD)⁵ to assess the digital readiness of Western Balkan economies in manufacturing. The DRD evaluates performance across four interrelated capability dimensions: (i) enabling infrastructure, (ii) production capabilities, (iii) innovation capabilities and (iv) digital capabilities. The analysis covers the 2015–

2024 period, with trade-based indicators available up to 2024 and all other dimensions assessed using the most recent available data (up to 2022). For benchmarking, the average of European Union (EU) countries' and Slovenia's individual performance are used as reference points.⁶

A multidimensional framework for digital manufacturing readiness

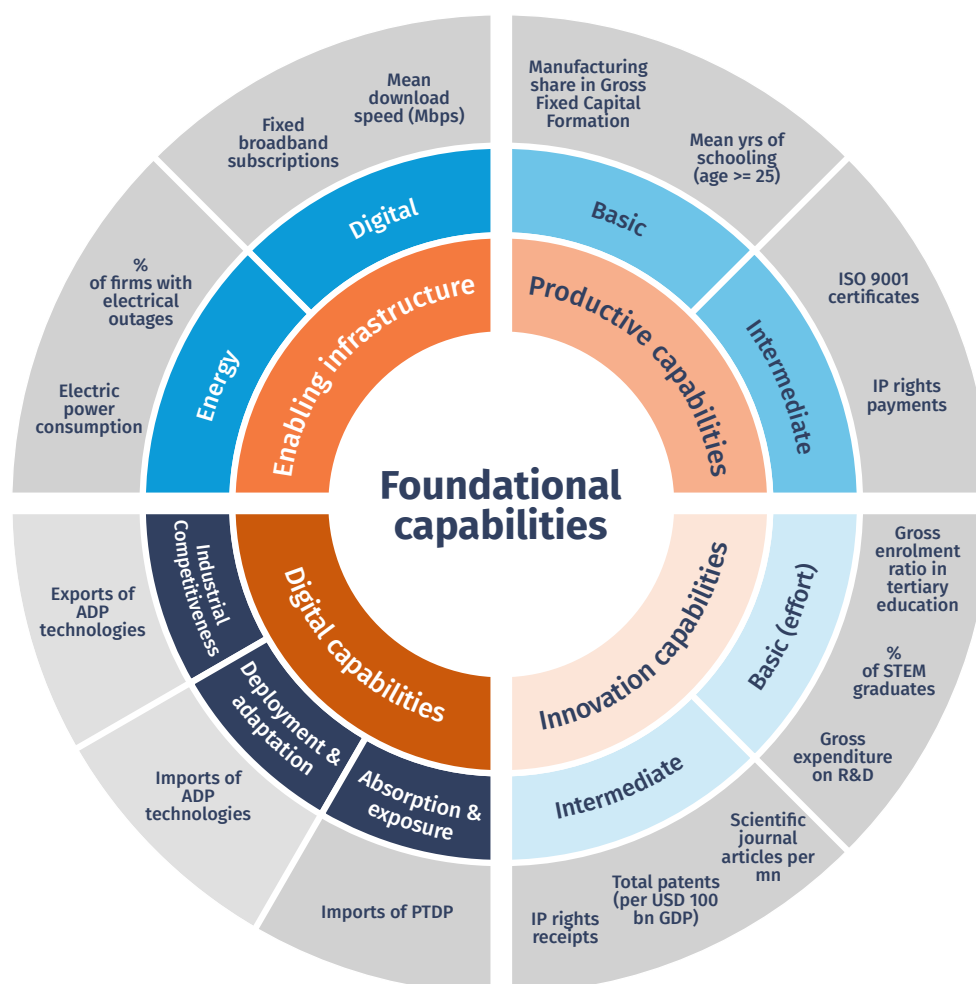
Digital readiness for manufacturing extends beyond mere access to technologies. It requires a comprehensive and cumulative set of capabilities that allows countries to integrate digital technologies into industrial processes, strengthen firms' technological capabilities and foster industrial upgrading. The UNIDO-GIZ Digital Readiness Dashboard operationalizes this understanding through 17 macro-level indicators organized across the four capability dimensions described above.⁷

The first dimension —*enabling infrastructure*— captures foundational energy, connectivity and digital access conditions required for firms to operate advanced production technologies and participate in digital manufacturing. The second one —*production capabilities*— reflects productive, organizational and technological capacities that enable efficient manufacturing, industrial upgrading and the absorption of advanced technologies. *Innovation capabilities*—the third dimension—measure countries' ability to generate, absorb and diffuse ADP technologies through skills development, research activity, patenting and technology-related knowledge flows. The fourth dimension —*digital capabilities*— encompasses countries' direct engagement with ADP technologies through trade-based proxies, reflecting their exposure to, deployment of and competitiveness in digital production technologies.

A distinctive feature of the DRD is its integration of a trade-based Digital Technologies Classification, which identifies tradable production technologies with digital potential (PTDP)⁸ and a subset of ADP products. By using imports and exports of such products as proxies for countries' engagement with digital technologies, the Dashboard links trade patterns to the formation of underlying digital capabilities in manufacturing.

Countries are evaluated against three complementary criteria: (i) performance relative to the other Western Balkan economies, (ii) performance relative to global averages for their income group, and (iii) trends over the 2015–2022 (or 2024) period. This multidimensional approach captures economies' structural position and their dynamic trajectories.

Figure 1 Dimensions and indicators of the Digital Readiness Dashboard



Source: IID Policy Brief No. 32, p. 4

Enabling infrastructure: Solid foundations, uneven reliability

The Western Balkans region shows a strong performance in most enabling infrastructure indicators. Relative to the global upper middle-income average, they generally outperform in electricity availability, access to digital connectivity and quality of digital services. The region as a whole exceeds the upper middle-income average in fixed broadband subscriptions per 100 people, reflecting sustained policy efforts to expand broadband infrastructure and promote the adoption of information and communication technology (ICT). Digital infrastructure is thus one of the region's clearest comparative advantages.

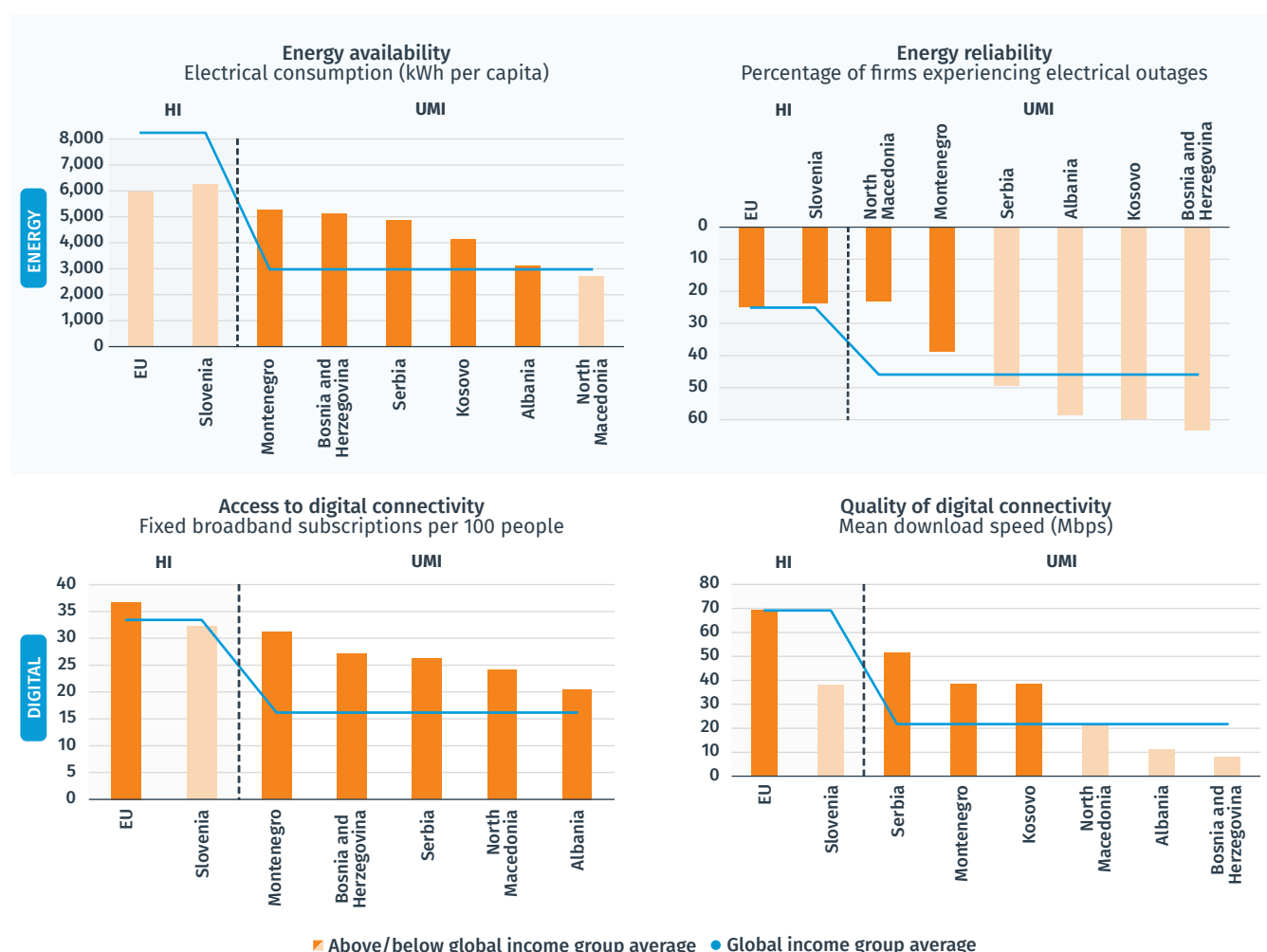
Most Western Balkan economies report mean download speeds above the global average for upper middle-income countries. However, important differences persist across countries and indicators. Montenegro stands out as the strongest regional performer in enabling infrastructure and is the only country with a strong performance across all four indicators in this dimension. Serbia follows closely, outperforming the upper middle-income country average in electricity availability and reliability, broadband access and internet quality, and reports the highest mean download speed in the Western Balkans. North Macedonia, Bosnia and

Herzegovina, Albania and Kosovo⁹ trail behind, though several countries have made progress in broadband access and electricity coverage.

Energy reliability remains a significant concern. Several countries report that high percentages of firms experience electrical outages, with Bosnia and Herzegovina and Albania recording the highest rates. Such reliability deficits carry serious implications for data-intensive and digitally enabled manufacturing processes that depend on stable, uninterrupted power supply.

Compared with the EU average, the region still lags in most infrastructure indicators, although the gap in access to digital connectivity and service quality is narrowing. This suggests that Western Balkan economies have made important gains in the infrastructural foundations for digital transformation, even if reliability and the quality of more advanced digital services remain uneven.

Figure 2 Country performance across indicators: Enabling infrastructure, 2022



Note: The indicator for energy availability relies on data availability. Columns in dark (light) indicate that countries (do not) outperform the global average of their respective income level. kWh = kilowatt hours; Mbps = megabits per second. HI: High-income, UMI: Upper middle-income.

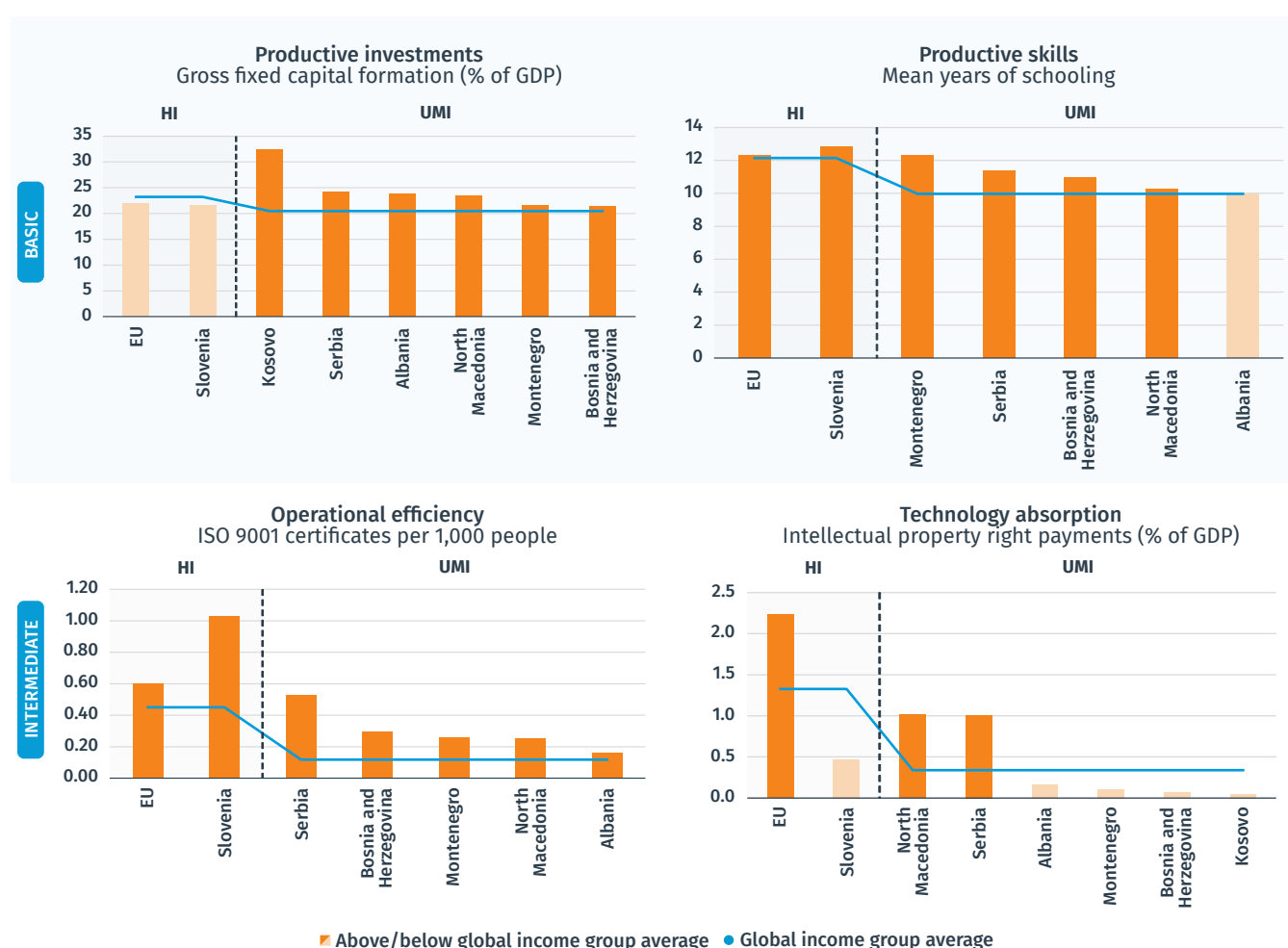
Source: Authors' calculations based on data from [Our World in Data](#) (top left), [World Bank](#) (top right, bottom left) & [M-Lab 2.0 Platform](#) (bottom right).

Production capabilities: Strong basic foundations, weaker intermediate capabilities

Western Balkan countries exhibit relatively strong production capabilities compared with their global peers across all indicators. Basic production capabilities, proxied by productive investment and average years of schooling, place the region above global averages for comparable income levels. The strongest results are observed in productive investment and productive skills, where several countries in the region approach or exceed high-income benchmarks, particularly in manufacturing investment.

By contrast, intermediate production capabilities—captured through operational efficiency (ISO 9001 diffusion) and technology absorption (intellectual property rights payments)—reveal a more mixed picture. The region remains well below the EU on both indicators, highlighting persistent gaps in firms' ability to organize production efficiently and absorb new technologies through quality management systems and related capabilities.

Figure 3 Country performance across indicators: Production capabilities, 2022



Note: Columns in dark (light) indicate that countries (do not) outperform the global average of their respective income level. GDP = gross domestic product. HI: High-income, UMI: Upper middle-income.

Source: Authors' calculations based on data from [World Bank](#) (top left, bottom right), [UNESCO Institute of Statistics \(UIS\)](#) (top right) & [The ISO Survey](#) (bottom left).

Nonetheless, all countries show positive trends in operational efficiency and technology absorption over the period 2015–2022, suggesting a gradual strengthening of organizational foundations for digital manufacturing. The Western Balkans' intermediate production capabilities consequently appear to offer one of the most favourable entry points for catching up.

Serbia emerges as the strongest performer in production capabilities across all four indicators, outperforming its income-group peers and recording positive trends throughout the period

of analysis. North Macedonia and Montenegro follow, with slightly lower but comparable scores, while Bosnia and Herzegovina, Albania and Kosovo perform weakest in this dimension. Taken together, the region's production capabilities can be characterized as having strong investment foundations, offset by uneven operational efficiency and persistent gaps in technology absorption relative to EU standards. These weaknesses continue to weigh on the Western Balkans' capacity to leverage existing assets for sustained industrial and digital upgrading.

Innovation capabilities: The main bottleneck for catching up

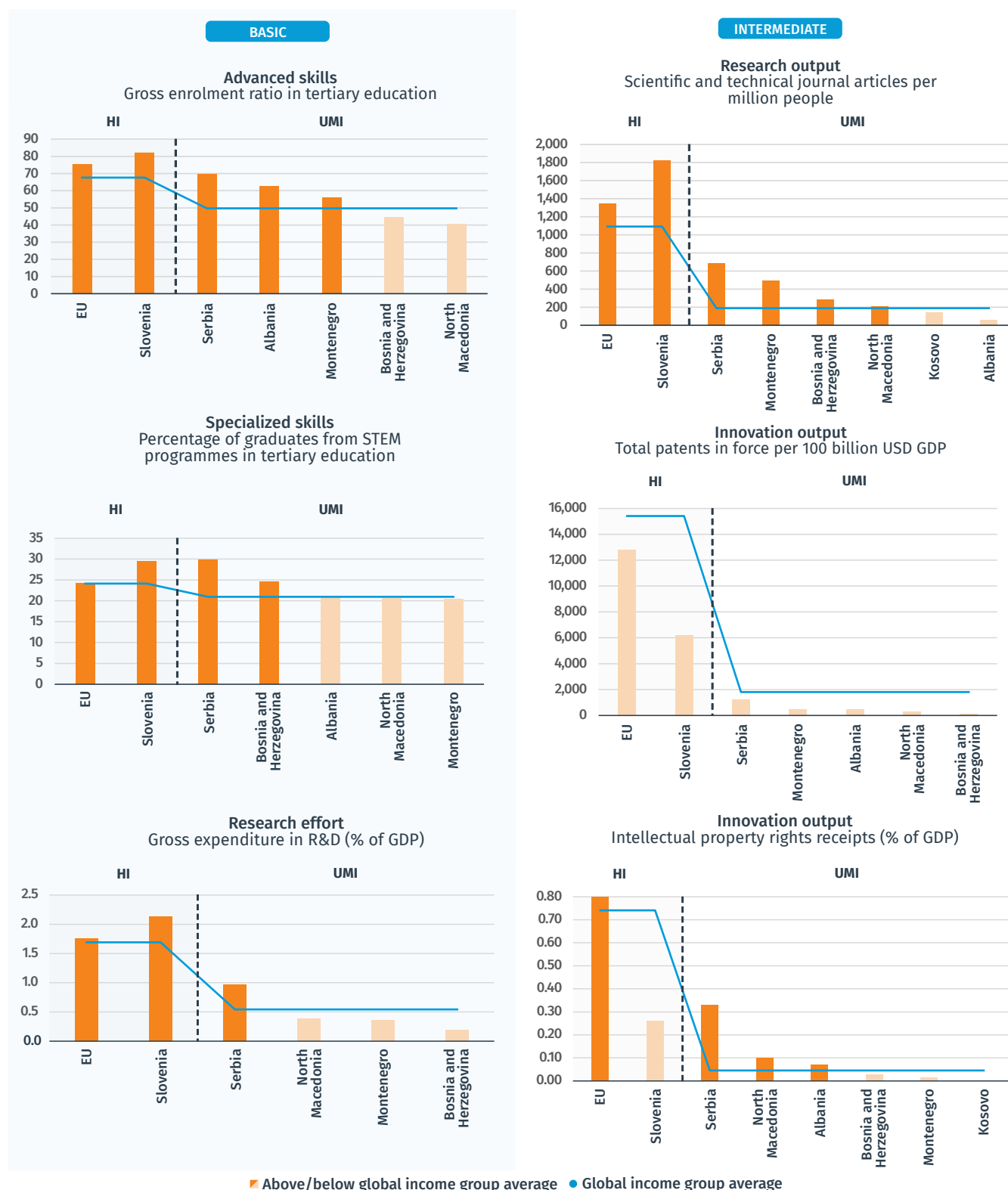
Innovation capabilities constitute the most binding constraint on the region's digital transformation. While the region outperforms the average of upper-middle-income economies in advanced and specialized skills, it continues to lag significantly behind the EU, pointing to a relatively narrow base of specialized human capital compounded by chronic underinvestment in research and development (R&D). Most countries fall below global benchmarks for R&D expenditure as a share of gross domestic product (GDP), underscoring chronic underinvestment in endogenous technological capability-building. These input-side deficiencies are reflected in a pronounced gap in innovation outputs. The region underperforms relative to the EU in scientific and technical publications, patents in force and intellectual property receipts, suggesting that existing human capital and research infrastructure are not being fully leveraged to generate commercially relevant innovation.

Serbia is the region's frontrunner¹⁰ in innovation capabilities, ranking highest across all six indicators. It is also the only country that reaches performance levels comparable to Slovenia

across several innovation indicators and even exceeds it on some measures related to intellectual property receipts. Montenegro, North Macedonia and Bosnia and Herzegovina show moderate performance, while Albania and Kosovo remain comparatively weaker.

A notable feature is the positive dynamism in the region's innovation-related indicators. Most countries show improvements over time in research output, specialized skills and innovation outcomes, particularly in scientific and technical publications, total patents in force and intellectual property receipts. This suggests that some of the capabilities needed for future digital upgrading are being built. However, persistent gaps in commercialization, patenting and research intensity point to a translation problem: human capital and research efforts are not yet being sufficiently converted into innovation outputs that support digital industrial development.

Figure 4 Country performance across indicators: Innovation capabilities, 2022



Note: Columns in dark (light) 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. HI: High-income, UMI: Upper middle-income.

Source: Authors' calculations based on data from [World Bank](#) (bottom left, top right, bottom right), [UNESCO Institute of Statistics \(UIS\)](#) (top left, middle left) & [WIPO IP Statistics Data Center](#) (middle right).

Digital capabilities: Stronger exposure, limited competitiveness

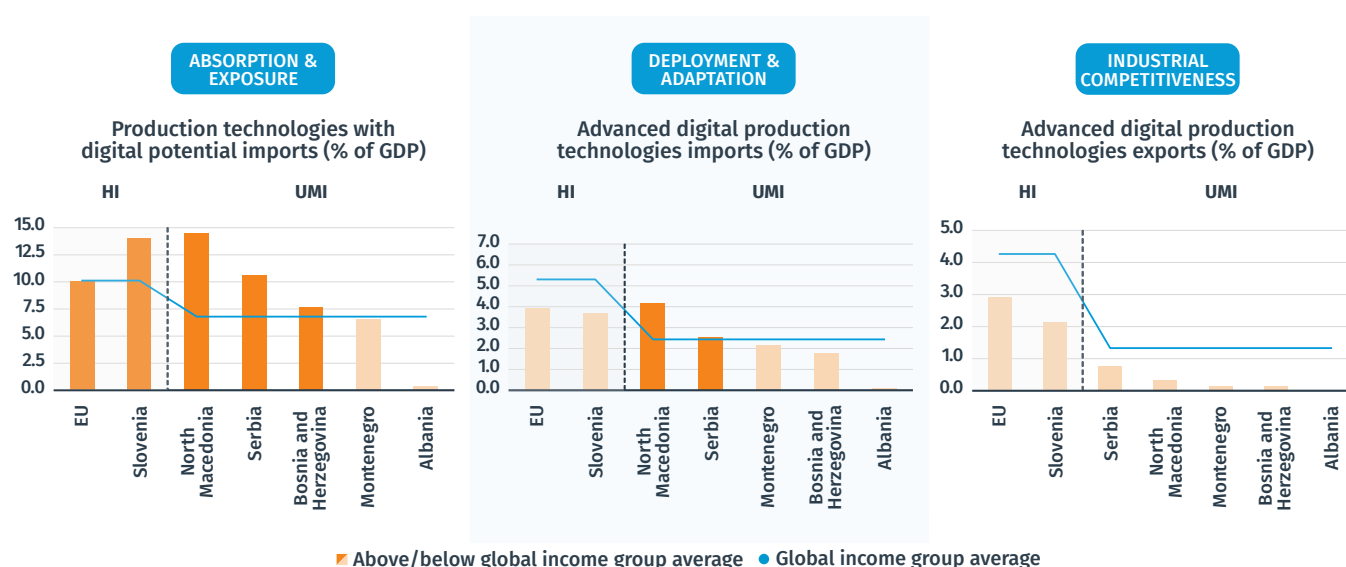
The digital capabilities dimension, which captures direct engagement with ADP technologies through trade-based proxies, reveals concentrated performance within the Western Balkans region despite generally positive dynamics. **The region outperforms the average upper middle-income country group in importing PTDPs, signalling growing exposure to and learning from digital manufacturing technologies.** This pattern is consistent with latecomer strategies in the current wave of digitalization and involves retrofitting and adaptation of existing technologies into digital processes. However, **the region remains slightly below the upper middle-income average in ADP technology imports, indicating a gap in engagement with more advanced digital technologies.**

North Macedonia and Serbia are the strongest performers in digital capabilities. North Macedonia stands out as the regional leader,

surpassing the upper middle-income average in both PTDP and ADP imports, and outperforming Slovenia in both indicators. Its import structure is notably diversified, with both parts and final products each accounting for more than 40 per cent of total ADP imports in 2024, indicating an advanced level of readiness for digital transformation in manufacturing relative to regional peers.

Serbia ranks a close second, with strong performance in both imports and exports of ADP technologies. It is the region's principal exporter of ADP technologies, accounting for over 80 per cent of total ADP exports across all three product categories over 2017–2024. Its trade in ADP technologies, however, is heavily concentrated in end-use products, in contrast to North Macedonia's more diversified structure. Montenegro performs moderately well, while Albania remains at low levels across all digital capability indicators.

Figure 5 Country performance across indicators: Digital capabilities, 2022



Note: Columns in dark (light) indicate that countries (do not) outperform the global average of their respective income level. ADP = Advanced digital production; GDP = gross domestic product. HI: High-income, UMI: Upper middle-income.

Source: Authors' calculations based on data from [World Bank](#) (middle) & [World Integrated Trade Solutions](#) (left, right).

Across the region, none of the countries exhibit strong performance in the export of advanced digital technologies, underscoring continued challenges in achieving global competitiveness. Most Western Balkan economies primarily remain users rather than producers of advanced digital technologies, reinforcing existing

structural asymmetries in the global digital production landscape. In this respect, the Western Balkans resemble latecomer economies that are still building capacity through importation, retrofitting and adaptation rather than through frontier innovation.

From connectivity to competitiveness

On the basis of the four capability dimensions, Serbia emerges as the strongest overall performer in the Western Balkans region. It leads in production and innovation capabilities, ranks second in enabling infrastructure and digital capabilities, and outperforms many of its global peers across a wide range of indicators. Montenegro records the strongest enabling infrastructure, while North Macedonia leads in digital capabilities. This illustrates that leadership varies across capability dimensions and is not concentrated in a single country. Bosnia and Herzegovina and Albania show more mixed performance, while Kosovo records weak overall results but is also constrained by substantial data gaps, particularly in digital capabilities.

Despite these differences, a common pattern emerges. All economies of the Western Balkans remain below EU benchmarks, with the largest gaps in the more advanced stages of capability accumulation. While the region has made notable progress in establishing the foundations for manufacturing digitalization, particularly

through improvements in infrastructure and production capabilities, innovation remains the principal bottleneck, and the adoption of ADP technologies is still limited and uneven. No country has yet developed balanced strengths across all four capability dimensions.

The findings suggest that the region's challenge extends beyond expanding digital connectivity. Converting connectivity into industrial competitiveness requires stronger innovation systems, broader diffusion of digital technologies across firms and enhanced regional coordination. As the Western Balkans advance their EU integration agenda, sustained and coordinated policy action across all four capability dimensions will be essential to build the cumulative capabilities needed for digital industrial transformation. UNIDO is already operationalizing this agenda in the region through the Smart Manufacturing Innovation Centre (SMIC) in Serbia, which supports manufacturing SMEs across the Western Balkans region in the digital and green transformation.

Policy recommendations

Advancing digital transformation in manufacturing across the Western Balkans requires integrated policy packages that simultaneously strengthen foundational capabilities and accelerate engagement with ADP technologies. The following recommendations build on the Dashboard's findings and are tailored to the region's diverse institutional and developmental contexts.

- 1. Accelerate 5G deployment for smart manufacturing.** Energy reliability gaps and limited high-speed connectivity constrain advanced digitalization in manufacturing. Governments should develop 5G strategies that explicitly target Industry 4.0 applications rather than focusing on consumer services; prioritize early 5G deployment in industrial zones and manufacturing clusters; and use public-private partnerships to reduce costs and extend coverage to strategic industrial areas. Grid reinforcement and power quality upgrades should be aligned with industrial digitalization strategies. The region's EU accession agenda provides a powerful framework for aligning such investments with EU digital and industrial standards.
- 2. Strengthen innovation ecosystems through enhanced R&D investment and STEM education.** Closing the innovation gap is central to leveraging digitalization for competitiveness. Governments should gradually increase public R&D spending and introduce tax incentives, matching grants and challenge funds for private R&D in digital manufacturing technologies. Science, technology, engineering and mathematics (STEM) programmes should be updated to align curricula with Industry 4.0 needs.

Strengthening innovation intermediaries, including technology centres and applied research institutes, is essential to translate research into industrial applications and to close the gap between research investment and commercially relevant innovation outputs.

- 3. Develop targeted MSME digitalization programmes with a manufacturing focus.** To catalyse productivity gains in manufacturing, governments should design programmes for micro, small and medium enterprise (MSME) based on digital maturity assessments tailored to production processes, such as the UNIDO Factory of the Future methodology being piloted in the region, to help firms identify opportunities for process monitoring, predictive maintenance and quality control. These programmes should provide subsidized access to ADP-related services and equipment, leverage public research infrastructure for shared digital manufacturing facilities, and create supplier development programmes linking MSMEs to digitally advanced lead firms.
- 4. Promote regional cooperation in ADP technology access and development.** Given the high concentration of ADP capabilities in a few economies (notably Serbia and North Macedonia), regional cooperation could broaden access to them and reduce duplication. Governments could establish regional centres of excellence for specific technologies; launch joint research and innovation programmes focused on ADP applications in priority value chains and facilitate technology transfer and knowledge sharing between leading and lagging

countries. Harmonizing technical standards, conformity assessment and digital certification would enable cross-border collaboration and support integrated digital manufacturing value chains. The shared EU integration agenda provides a natural framework, including alignment with programmes such as Horizon Europe and Digital Europe.

- 5. Build comprehensive and coherent national policy frameworks for digital industrial transformation.** While several Western Balkan countries have adopted Industry 4.0 strategies, implementation remains fragmented across ministries and policy domains. Governments should establish coordination mechanisms linking industrial, digital and skills policies; use regulatory sandboxes to accelerate technology testing and monitor progress across all four capability dimensions, disaggregated by firm size and region. Long-term financing instruments, including blended finance and development bank credit lines, should support technology acquisition and capability development while ensuring coherence across digitalization, industrial development and MSME support strategies.

Key risks and safeguards

To ensure inclusive and resilient digital transformation, policy packages should incorporate the following safeguards from the outset:

- 1. Address digital divides and unequal distribution.** Connectivity and support risk becoming concentrated among larger firms and capital regions. Policymakers should set inclusion targets for MSMEs and lower performing regions, tracking participation and outcomes by location, industry and firm size. Kosovo's limited engagement across

capability dimensions underscores the risk of intra-regional divergence if targeted support is not provided.

- 2. Foster digital-green alignment.** Digital infrastructure and data processing increase electricity demand. Industrial digitalization should therefore be aligned with energy efficiency and cleaner power strategies to avoid high-carbon trajectories, particularly in energy-intensive economies reliant on coal-based power.
- 3. Strengthen cybersecurity and resilience.** Connected production systems face growing cyber risks and operational disruptions. Minimum safeguards should include baseline cybersecurity standards, incident-response procedures and resilience planning for industrial zones, aligned with EU cybersecurity frameworks and EU integration commitments.
- 4. Prevent technology dependency and lock-in.** Heavy reliance on a narrow set of vendors and platforms can increase costs and reduce strategic autonomy. Policies should promote interoperability and open standards where feasible, while prioritizing solutions that strengthen local ecosystems, particularly in the region's smaller economies.
- 5. Support skills transition and mitigate social impact.** Adoption of ADP technologies may displace some tasks while increasing demand for higher-skilled roles. Digitalization programmes should include retraining and mid-career upskilling for technicians and operators, alongside certification pathways that facilitate just transitions in industrial labour markets.

Endnotes

1. This policy brief is one of a series applying the same methodology to assess digital industrial capabilities across different regions. Related briefs on Latin America and the Caribbean (LAC) and the BRICS Plus countries are available here: [From Connectivity to Competitiveness: Foundational Capabilities for Manufacturing in Latin America](#) and [From Scale to Synergies: Digital Readiness for Manufacturing in BRICS Plus](#).
2. Advanced Digital Production (ADP) technologies are multipurpose technology clusters integrating software, hardware and connectivity with applications across R&D, process innovation, product innovation and supply-chain management. For a detailed discussion, see UNIDO (2019), [Industrial Development Report 2020: Industrializing in the Digital Age](#).
3. Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia and Serbia.
4. This brief is based on Santiago, F., Heredia Zurita, A. and Savrasov, A. (2026), *Exploring the Western Balkans' Readiness for Digitalization in Manufacturing (2015–2024)*, Vienna, UNIDO. For methodological details, see UNIDO and GIZ (2024), [Digital Diagnostics: Stairway to Industry 4.0 and Digital Technology Competitiveness](#), Tool 8, EQUIP Toolkit.
5. For detailed information on the Digital Readiness Dashboard (DRD), see UNIDO and GIZ (2024), [Digital Diagnostics: Stairway to Industry 4.0 and Digital Technology Competitiveness](#), Tool 8, EQUIP Toolkit.
6. Slovenia was included as a suitable benchmark for the region given its proximity in terms of industrial structure and its status as an EU member state with a comparatively well-developed manufacturing base.
7. Kosovo reported data for only 7 of the 17 indicators in the DRD, and none for the digital capabilities dimension (trade in PTDP and ADP technologies). As a result, Kosovo's position in the regional rankings combines performance gaps where data exist (notably in production and innovation capabilities) with constraints due to missing or incomplete data, particularly for digital capabilities.
8. PTDP technologies refer to tradable production equipment and machinery whose capabilities can be significantly enhanced through digital upgrades such as sensors, automation and connectivity.
9. This designation is without prejudice to positions on status and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.
10. "Frontrunners" are economies that lead in the production of ADP technologies and are defined as the top 10 economies in terms of cumulative global patent family applications in these technologies. "Latecomers" are economies with some engagement with ADP technologies but less than follower economies (UNIDO, 2020).



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