

OLIMPIJA HRISTOVA ZAEVSKA

**ACCELERATED WESTERN BALKAN
INNOVATIVE GROWTH WITH
INDUSTRY 4.0 ECOSYSTEMS**

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Accelerated Western Balkan Innovative Growth with Industry 4.0 Ecosystems

Industry 4.0 Transformative Potential for Competitiveness

Industry 4.0 (I4) emerged as a strategic concept in 2011. The term was first coined by the German Government Council in an effort to position Germany as a global leader in manufacturing engineering (Kagermann et al. 2013; Patnaik 2020). The World Economic Forum's 2016 theme, "Mastering the Fourth Industrial Revolution," further promoted the concept in global discourse, highlighting its significance for both scholars and practitioners, as well as policymakers. This vision presents not only a technological shift but also a political ambition to create a competitive advantage among nations.

I4 is considered an industrial revolution encompassing a set of technologies that include big data analytics, cloud computing, artificial intelligence (AI), Internet of Things (IoT), cybersecurity, 3D printing, autonomous robots, and augmented reality. Unlike

previous industrial revolutions, I4 is uniquely characterized by the *integration* of these technologies and machines, as well as by blurring the cyber-physical divide. I4 revolutionizes manufacturing by merging cyber-physical systems, enhancing digitalization, automation, and interconnected value chains. This shift drives efficiency, fosters innovation, and transforms firm performance by replacing outdated systems and sparking socio-economic growth (Zaevska 2024). However, the high costs of I4 adoption, both financial and knowledge-based, pose significant barriers, particularly for small and medium-sized enterprises (SMEs) in countries lagging in innovation, including the Western Balkans 6 (WB6) countries. Without targeted actions, this region risks falling behind in innovation compared to advanced economies, entrenching economic disparities.

Comprehending the nature and implications of I4, many developed countries have made I4 a key political ambition since 2013 and a determinant of national economic competitiveness. Therefore, they crafted dedicated policies such as Germany's "Industrie 4.0," France's "La Nouvelle France Industrielle," Canada's "Industrie 2030," and Italy's "Piano Nazionale Industria 4.0," or integrated them into existing industrial or smart specialization policies. These initiatives often include financial support through tax benefits, infrastructure investments, and sponsorships. The World Economic Forum, for example, supports Centers for the Fourth Industrial Revolution globally to foster multistakeholder dialogue and cooperation on I4 technologies.¹ The EU also invested in "Factories of the future" and European Digital Innovation Hubs (DIHs),² which largely focus on I4.

Over the past decade, policymaking aimed at supporting the adoption and innovation of I4 has focused on establishing various hubs, labs, and research transfer organizations (RTOs). Although these hubs are prominent in many developed countries,

¹ Industry 4.0 Centers – World Economic Forum <https://centres.weforum.org/centre-for-the-fourth-industrial-revolution/home>

² European Digital Innovation Hubs <https://digital-strategy.ec.europa.eu/en/policies/edihs>

the specific types of Industry 4.0 hubs that have emerged in developing countries, such as the WB6 countries – Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Kosovo, and Serbia – and their efficiency in fostering innovation remain unclear.

This essay maps Industry 4.0 ecosystems (I4ESes) across WB6 countries, as well as comparator countries Croatia and Slovenia, applying Zaevska's Industry 4.0 ecosystem (I4ES) concept (2024) and the European Digital Innovation Hub database (EDIH). After mapping, the essay discusses the structure and value creation of I4ESes, followed by an analysis of how their emergence relates to regional and country-level innovation using the European Innovation Scoreboard.³ Finally, it provides policy recommendations for the effective use of I4ESes to support innovation and competitiveness.

An Ecosystem Approach for I4 Adoption and Innovation

Firms adopting I4 technologies must develop increasingly cognitive and relational capabilities, strengthening relationships with external partners and organizations throughout the adoption process. Traditional dyadic relationships, such as those found in conventional supply chains or isolated firm-level innovation efforts, are inherently insufficient to address the multifaceted complexities and resource demands of I4.

The increasing proliferation of “Fab Labs” or “factories of the future” and the extensive European Digital Innovation Hub (EDIH) initiative, with over 700 initiatives across Europe and around 400 focused on I4 technologies, underscore the growing global recognition of collaborative spaces as essential for I4 advancement. By facilitating shared infrastructure, pooling expertise, and enabling collective knowledge, an ecosystem can significantly reduce the individual cost burden for firms, particularly SMEs.

³ European Innovation Scoreboard. European Commission. https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_en

The ecosystem theoretical approach, as discussed in the strategy and innovation literature including regional innovation, offers a unique lens to observe collaborations among diverse actors gathered around a set of I4 technologies that span a single technology or sector. Specifically, building on ecosystem theorizing by Jacobides, Cennamo, and Gawer (2018), Adner (2017), and most recently, Baldwin and co-authors (2024), Zaevska defines Industry 4.0 ecosystems (I4ESes) as *collaborations of diverse, autonomous, non-hierarchical actors, including firms, universities, government agencies, and NGOs, that bring non-generic Industry 4.0 technology knowledge and funding to the ecosystem and aim to support I4 technology adoption or innovation* (Zaevska, 2024).

Ecosystems are fundamentally distinct from more traditional organizational structures such as supply chains, clusters, strategic alliances, or networks, with several characteristics that set them apart. I4ESes thrive by integrating *diverse actors*, including governments, which drive strategic goals or funding; universities, which contribute knowledge and research; and firms and other actors. These ecosystems feature *dynamic, non-hierarchical relationships* where actors' roles, such as orchestrating (loose management) or persuading, are fluid and trust-based, fostering voluntary collaboration for mutual benefit (Autio, 2021; Benedict & Sebastian, 2024). Actors provide unique, non-generic resources that can include knowledge, funding, and technology not easily accessible on the market, thereby creating specialized complementarities (Jacobides et al., 2018). They can focus on a *single I4 technology* (e.g., robotics) or a *diverse range of I4 technologies*. Effective ecosystems also bridge the gap between frontrunners and laggards, enabling successful collaboration despite varying levels of leverage and stakes, and *democratizing access to knowledge and innovation* (Zaevska, 2024).

I4ESes that we see emerging across Europe, in the form of DIHs, not only impact firms but also significantly affect the geography of knowledge production, manufacturing, and innovation (Gress and Kalafsky 2015), as well as local techno-industrial production systems. Based on the literature on external knowledge seeking and knowledge relatedness, the central premise is that

when more diversified technologies are present in I4ESes, more cross-fertilization of ideas will occur, enabling innovation (Katila and Ahuja 2002; Laursen and Salter 2006). But how effective are they in supporting innovative transformation?

Industry 4.0 Ecosystems Across WB6

European Digital Innovation Hubs (DIHs) that specifically focus on Industry 4.0 technologies are practical examples of I4ESes in various countries, including the WB6, Croatia, and Slovenia. Prior research on I4ESes across EU regions has shown that I4ESes have a positive impact on regional-level innovation, mainly through firms launching new-to-market products; however, there is no significant positive impact on patenting (Zaevska 2024).

For this brief, all EDIHs (proxy for I4ESes) across WB6 were mapped using the EDIH database. A comparative qualitative analysis was conducted on the content present in the database and these countries' digital content (websites and news), including Croatia and Slovenia, which served as comparator countries. In parallel, the European Innovation Scoreboard data on overall innovator category, as well as two typical measures of innovation – launch of new-to-market products and patenting – were considered, as well as their correlation with the number and type of I4ESes.

WB6 exhibit a strong overlapping sectoral focus on some I4 technologies, specifically *artificial intelligence and cybersecurity*, but also a more general focus on *digital transformation* (Table 1). Most countries established DIHs – I4ESes in 2020-2025.

Serbia has four EDIHs concentrated in Belgrade and one in Novi Sad, specializing in information technology, biotechnology, and cybersecurity. Key DIHs, such as STP Belgrade, BRH, and BITF, focus on AI, blockchain, and robotics. North Macedonia has a single DIH, INNOFEIT, based in Skopje, dedicated broadly to digital transformation. Bosnia and Herzegovina has two DIHs – ONEX and INTERA Technology Park – primarily focused on additive manufacturing and AI.

Albania has introduced DiVA Digital Valley Albania 1.0, focusing on digital transformation initiatives to support the country's digital ecosystem. Kosovo is home to the DIG-4K Innovation and Training Park (ITP), located in Prizren, which provides support for collaboration among innovation activities, research and development stakeholders, training and educational institutions, and start-ups. Montenegro has established the MontEDIH Digital Innovation Hub, dedicated to supporting the digital transformation of Montenegrin companies and the public sector.

Overall, it can be observed that I4ESes (existing DIHs) in the WB6 follow a non-hierarchical structure, with mainly universities or government institutions leading them. The value proposition primarily focuses on *general digitalization*. Government institutions mainly contribute funding and strategic oversight; universities bring knowledge, while companies serve as both knowledge providers and beneficiaries. Overall, I4ESes promote collaborative mechanisms for digitizing manufacturing, large-scale projects, and open innovation among various local and regional actors, such as accelerators, universities, tech parks, SMEs, start-ups, and business groups.⁴ Yet, although firms in the WB6 economies recognize the need for digital transformation, few are willing to invest in DIH services that would support their digitalization efforts.⁵ For this reason, many of the DIHs are nascent, usually co-funded by the European Union and respective national governments, and offer free services.

Beyond providing direct support to businesses, DIHs are often perceived as implementing mechanisms of competitiveness policies, such as Smart Specialization Strategies (S3) and INNOFEIT in North Macedonia, which helps improve public administration efficiency.

⁴ RCC. (2021). Mapping of Digital Innovation Hubs. Regional Cooperation Council.

⁵ Ibid.

Table 1: DIHs – Industry 4.0 Ecosystems across WB6, Croatia, and Slovenia

Country/ Innovation Category ⁶	EDIHs/Regions	Sectoral Focus	Economic & Regional Impact
 SRC-EDIH Europe's digital innovation ecosystem  DIGI-SI  DIH DIGITAL INNOVATION HUB SLOVENIA  DIH AGRIFOOD  AGRIFOOD DIGITAL INNOVATION HUB  HEALTHWISE Digital Innovation Hub  HPC5  DIGI-SI  MIOH-S  JSI Zahodna Slovenija – Strong SRC-EDIH GreenPulse 5.0 Digital Innovation Hub Slovenia DIH AGRIFOOD DIH for digital twins of logistics systems and manufacturing processes, and systems Healthwise Digital Innovation Hub HPC5 DIGI-SI MIOH-S Vzhodna Slovenija 4PDIH JSI	Zahodna Slovenija – Strong SRC-EDIH GreenPulse 5.0 Digital Innovation Hub Slovenia DIH AGRIFOOD DIH for digital twins of logistics systems and manufacturing processes, and systems Healthwise Digital Innovation Hub HPC5 DIGI-SI MIOH-S Vzhodna Slovenija 4PDIH JSI	Smart Cities, Cybersecurity, Agrifood, AI, Health-Tech	Strong EU integration, export-oriented, focus on green & digital economy
 AI4health CRO  ALGEBRA LAB  CROBOHUB++  hub cratech  Innovation centre Nikola Tesla ENT  R3  3D grupa  Klaster 3D tehnologija DIH North Digital Innovation Hub Grad Zagreb – Strong AI4HEALTH.CRO Algebra LAB CROBOHUB CroTechHub CybersecRDI INOVAČIJSKI CENTAR NIKOLA TESLA RBI DIH SMIH 3D – Smart 3D Industry Hub CROBOHUBplusplus Sjeverna Hrvatska – Emerging DIH North	Grad Zagreb – Strong AI4HEALTH.CRO Algebra LAB CROBOHUB CroTechHub CybersecRDI INOVAČIJSKI CENTAR NIKOLA TESLA RBI DIH SMIH 3D – Smart 3D Industry Hub CROBOHUBplusplus Sjeverna Hrvatska – Emerging DIH North	AI in Healthcare, Industry 4.0, Robotics, Agritech	Strengthening manufacturing, agritech exports, and AI adoption

	DIH PANNONIA DIH TERA hub.in Bjelovar InfoDesignHub Panonska Hrvatska - Emerging AI and Gaming EDIH Jadranska Hrvatska - Emerging EDIH Adria AgriFood Croatia		
Serbia - Emerging 	BioSense Institute BRH BITF STP Belgrade	AI, Precision Agriculture, Fintech, Robotics	Leader in AI- driven agritech, expanding fintech & cybersecurity
North Macedonia - Emerging 	INNOFEIT	AI, Cloud Computing, Smart Cities	Committed to digital infrastructure, public sector transformation
Kosovo - Emerging 	DIG-4K	Startups, ICT, Green Energy, Digi- tal Skills	Job creation, en- trepreneurship growth, 2,000+ learners trained in 2024
Montenegro - Emerging 	MontEDIH	AI, IoT, Blockchain, HPC	Early-stage development, potential for modernization in key industries, awaiting concrete implementation

Bosnia & Herzegovina - Emerging  	DIH ONEX Foundation for innovation and technology development, INTERA Technology Park	Manufac- turing, SME digitaliza- tion, Industry 4.0	Strong business incubation, EU project participation
Albania 	DiVA	Digital Policy, SME Support	No proven impact, awaiting concrete implementation

⁶ The European Innovation Scoreboard (EIS) categorizes countries and regions into four groups based on their innovation performance relative to the EU average: Innovation Leaders (above 125%), Strong Innovators (100%-125%), Moderate Innovators (70%-100%), and Emerging Innovators (below 70%) https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_en

3.1 Industry 4.0 Ecosystems and Regional Innovation Dynamics

Besides the importance of I4ESes for companies, research indicates that the presence of I4ESes (DIHs) has a positive impact on specific aspects of regional innovation, particularly leading to increased new-to-market product sales and improved product/process innovation metrics (Zaevska, 2024). Many regions across EU countries, especially since 2021, have experienced a notable increase in product innovation, specifically in new-to-market sales. This suggests that I4ESes effectively contribute to the adoption of technology and the commercialization of new products.

From the analyzed countries and regions, Grad Zagreb and Zahodna Slovenija are considered Strong Innovators, as per the EIS, and exhibit higher concentrations of EDIHs (10 and nine, respectively). This suggests a positive correlation between a denser network of EDIHs and a higher overall innovation score. These regions consistently exceed EU averages in aspects such as tertiary education levels and international scientific collaborations, but not in patenting.

Vzhodna Slovenija and Belgrade are Moderate Innovators, with Vzhodna Slovenija (two EDIHs) displaying fluctuating performance across different indicators. While it shows above-average patenting at times, its new-to-market sales remain inconsistent. Belgrade (3 EDIHs) exhibits the opposite pattern: consistently high new-to-market sales but very low patenting rates.

Jadranska Hrvatska, Panonska Hrvatska, Sjeverna Hrvatska, Albania, Bosnia and Herzegovina, Montenegro, and North Macedonia are all classified as Emerging Innovators. While some regions, like Jadranska Hrvatska and Panonska Hrvatska, have demonstrated some growth in product and process innovation and new-to-market sales, especially since 2021, their patenting activity remains consistently low. Montenegro stands out with high new-to-market sales but extremely low patenting rates.

Discussion

Many regions saw a marked increase in new-to-market sales after 2021, and this trend is potentially supported by I4ESes; other reasons may involve post-pandemic economic shifts or other specific policy initiatives. At the same time, across most regions, patenting activity lags significantly behind the EU average, regardless of the presence of I4ESes, highlighting a potential disconnect with more transformative (radical) innovation. These persistent findings, even in countries with a longer tradition of EDIHs (Slovenia and Croatia), point to the untapped potential of I4ESes to support and translate innovation into commercially viable, protected intellectual property. Consequently, this poses a major challenge for the long-term innovation prospects of WB6, given the importance of intellectual property for technological transformation and leapfrogging.

This observation underscores the need for a nuanced evaluation of I4 support initiatives in WB6. Like other regions in Europe, regardless of the number of I4ESes, these countries also show poor performance in patenting. This outcome might be due to I4Es' limited funding, loose management structures, but also a lack of technological specialization.

Specifically, EDIHs are co-financed with 50% from the EU's Digital Europe Programme, allocating EUR 750 million for 2021–2027, and 50% from national, regional, or private sources, providing each hub with EUR 1–2 million annually to support SMEs in adopting Industry 4.0 (I4) technologies like AI and automation (European Commission, 2021a). This limited financing, particularly the constrained national budgets in smaller economies (e.g., EUR 0.5 million per hub annually), likely hinders radical innovation, as it prioritizes incremental adoption over high-risk, high-reward R&D needed for patentable breakthroughs (World Bank, 2022). Insufficient funding for advanced infrastructure and research collaborations, coupled with loose management and a not-for-profit model that limits revenue reinvestment, may pose a key obstacle to transformative I4 mastery in the region (European Commission, 2021b).

Additionally, a loose management structure without clear roles might hinder effectiveness and clarity for actors wanting to join. These aspects warrant further scrutiny, as they are key for benchmarking an effective support model for WB6 to increase I4 adoption and innovation. Yet current findings suggest few directions.

Finally, the technological focus of EDIHs seems to be geared towards integrating multiple I4 technologies at once (IoT, robotics, cybersecurity, AI), which provides technological breadth but not depth. Such technological diversity and cross-fertilization of ideas may yield new ideas for innovation, but patenting continues to rely on deeper specialization.

Utilizing Industry 4.0 Ecosystems as Strategic Innovation Steering Wheel

The analysis across WB6 as well as Slovenia and Croatia showcased that even with relatively few I4ESes, some regions exhibited strong growth in innovation-related sales and product/process innovations. For example, EDIH Adria explicitly states that companies develop around 30,000 new products and services annually in Croatia, yet 95% of those do not go to market. Thus, EDIH Adria⁷ clearly signals that it aims to support companies in launching new-to-market products – an aspect I4ESes are shown to be good at. Others, despite having many I4ESes, have shown limited increases in patenting. This complexity underlines the need to design I4ESes with a clear idea of the kind of innovation they aim to support and how they combine with regional factors such as the level of existing related knowledge and absorption capacity.

Second, accurately assessing the characteristics of knowledge in a region enables the design of I4ESes as effective policy interventions. This represents a move beyond a generic design of “innovation hubs” to a demand for highly targeted, evidence-based design. Policymakers should conduct rigorous diagnostics of re-

⁷ EDIH Adria <https://edihadria.eu/>

gional industrial structures, existing knowledge bases, and available and potential skill sets to ensure that established I4ESes are precisely tailored to leverage local strengths and address specific regional needs, rather than adopting a one-size-fits-all model. Such precision will maximize impact and resource efficiency.

Third, the ecosystem needs to choose a focal I4 technology to attract the right actors and push forward not only product innovation but also patenting.

Fourth, I4ESes necessitate better orchestration. Although I4ESes are effective spaces for testing, networking, and tailoring technology, they can leverage more resources with a stronger governance structure and process. EDIHs must strike a balance between being democratic – open to all types of actors – and strategic in supporting innovation that can be protected, thereby delivering bigger returns and advancing innovation. Governments play a crucial role in establishing a conducive atmosphere for innovation in I4 by developing supportive policies and regulations, as well as regulatory sandboxes within I4ESes.

Finally, the financing of I4ESes should also be optimized, primarily by assessment and optimization of current funding. When I4ESes have a well-designed financial model, they can attract the private sector via mechanisms such as industrial PhDs, Public-Private Partnerships (PPPs), blended finance, and increased collaboration with multinational development banks, since governments and EU funding alone cannot meet all demands.

As the WB6 stand at a crossroads, the window to catch up with advanced economies narrows. A decade of European experience with these ecosystems reveals their prowess in training and incremental digitalization, but there is still a gap in driving radical innovation. Learning from this, WB6 policymakers can reimagine ecosystems as focused, well-managed catalysts for transformative innovation. Without elevating their role, the region risks remaining entrenched as emerging innovators and missing the technological leap needed to thrive in an era of heightened global competitiveness.

References:

- Adner, R. (2017). Ecosystem as structure: An actionable construct for strategy. *Journal of Management*, 43(1), 39–58.
- Autio, E. (2021). Orchestrating ecosystems: A multilevel framework. *Innovation: Organization & Management*, 24(1), 1–22.
- Baldwin, C. Y., & others. (2024). The architecture of collaboration: Designing ecosystems for value creation. *Harvard Business Review*.
- European Commission. (2020). *Economic and Investment Plan for the Western Balkans*.
- European Commission. (2021a). *Digital Europe Programme: European Digital Innovation Hubs Work Programme 2021–2023*.
- European Commission. (2021b). *Questions and Answers: European Digital Innovation Hubs in Digital Europe Programme*.
- Benedict, M., & Sebastian, I. M. (2024). Trust-based ecosystems: A new model for innovation. *MIT Sloan Management Review*.
- Gress, D. R., & Kalafsky, R. V. (2015). Geographies of production in Industry 4.0: Spatial implications of technological change. *Geoforum*, 66, 139–147.
- Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic Management Journal*, 39(8), 2255–2276.
- Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative Industrie 4.0. *Acatech – National Academy of Science and Engineering*.
- Katila, R., & Ahuja, G. (2002). Something old, something new: A longitudinal study of search behavior and new product introduction. *Academy of Management Journal*, 45(6), 1183–1194.
- Laursen, K., & Salter, A. (2006). Open for innovation: The role of openness in explaining innovation performance among U.K. firms. *Strategic Management Journal*, 27(2), 131–150.

Mayers, J., & Williams, A. (2020). *Ecosystem edge: Sustaining competitiveness in the face of disruption*. Stanford Business Books

Moore, J. F. (1993). Predators and prey: A new ecology of competition. *Harvard Business Review*, 71(3), 75–86.

Patnaik, S. (2020). Industry 4.0: Opportunities and challenges for manufacturing. *Journal of Manufacturing Systems*, 57, 112–124.

Zaevska, O. H. (2024). *Industry 4.0 Ecosystems: Structure, Value Creation and Impact on Regional Innovation*. Copenhagen Business School PhD Series

OECD. (2023). *Competitiveness in Southeast Europe: A Policy Outlook*. OECD Publishing.

World Bank. (2022). *Western Balkans Digital Economy: Challenges and Opportunities*. <https://www.worldbank.org/en/region/eca/publication/western-balkans-digital-economy>

