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Danube DNA

A 1.2

Analysis of smart specialization strategies in each Danube country, mapping of particular digital readiness levels by country and industry sector along the Danube Region

D.1.2.2

Map of the digital readiness by country and industry sector along the Danube Region

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List of Abbreviations

ADP: Advanced Digital Production
AT: Austria
BG: Bulgaria
BiH: Bosnia and Herzegovina
CIS: Computer and Information Services
CZ: Czech Republic
DE: Germany
DESI: Digital Economy and Society Index
EQuIP: Enhancing the Quality of Industrial Policies
EU: European Union
GFCF: Gross Fixed Capital Formation
HR: Croatia
HU: Hungary
ICT: Information and Communication Technology
IPR: Intellectual Property Rights
MNE: Montenegro
R&D: Research and Development
RO: Romania
RS: Serbia
S3: Smart Specialisation Strategies
SL: Slovenia
SMEs: Small and Medium Enterprises
STEM: Science, Technology, Engineering, and Mathematics
SV: Slovakia
UNIDO: United Nations Industrial Development Organization

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1. Introduction

Digital readiness plays a crucial role in shaping the competitiveness and innovation potential of regions in the modern economy. This report builds upon the findings presented in D1.2.1 and extends the analysis through a detailed Digital Readiness Assessment. The methodology is grounded in the selection of key indicators inspired by precedent studies on Digital Readiness Level determination. These indicators are systematically analyzed and visualized in the form of a Digital Readiness Heatmap, providing an intuitive yet comprehensive snapshot of regional performance across the Danube Region.

The heatmap not only highlights current strengths but also pinpoints areas requiring strategic investments, fostering a deeper understanding of how individual countries and industries are positioned in terms of digital infrastructure, capabilities, and innovation. Under the framework of the European Commission's Smart Specialization Strategies (S3), this tool enhances decision-making by offering a numerical foundation for assessing the digital readiness of stakeholders. By combining these quantitative insights with the S3 framework, the report equips policymakers with actionable intelligence to drive sustainable, inclusive digital transformation.

The analysis focuses on four foundational pillars: enabling infrastructure, production capabilities, innovation capabilities, and digital capabilities. These dimensions collectively provide a robust evaluation of each country's preparedness to engage with and benefit from digital transformation. By leveraging tools such as UNIDO's EQuIP framework and benchmarking methodologies, the report provides a thorough assessment of the region's standing in international digitalization efforts.

As regions navigate the complex demands of digital transformation, the findings in this report offer a roadmap for enhancing digital competitiveness. By integrating data-driven insights with tailored strategies, stakeholders in the Danube Region are positioned to address existing challenges and harness opportunities for long-term growth in the digital economy.

2. Digital Readiness Assessment

2.1 Digital Diagnosis

To provide a more comprehensive view, we conducted a quantitative assessment using UNIDO's EquIP (Enhance the Quality of Industrial Policies) tool. Created by the United Nations Industrial Development Organization (UNIDO), an agency dedicated to fostering inclusive and sustainable industrial growth, this toolkit represents a significant step in empowering developing nations to shape their industrial futures (UNIDO, 2024). Our digital diagnosis analysis specifically employed Toolkit 8, "Industrial Policy Processes and Institutional Framework," which focuses on governance and implementation aspects of industrial policy.

The toolkit offers policymakers a comprehensive approach to assess a country's readiness for the Fourth Industrial Revolution, particularly in the context of manufacturing digitalization. Additionally, it reviews the policy and regulatory environment to ensure that it fosters digital innovation and addresses the identified gaps, enhancing competitiveness and technological adoption (UNIDO, n.d.).

The framework is built around three key layers of foundational capabilities and a fourth layer, which evaluates a country's capacity to integrate production technologies with digital potential and its success in importing advanced production technologies (ADP):

- **Enabling Infrastructure:** This foundational layer recognizes that digital technologies require reliable energy and high-quality digital connectivity.
- **Production Capabilities:** distinguish between basic capabilities (like the ability to invest and basic skills) and intermediate capabilities (like operational efficiency and technology absorption).
- **Innovation Capabilities:** This layer looks at both innovation efforts (like research spending and advanced skills) and innovation outputs (like patents and scientific publications).
- **Digital Capabilities:** This final layer assesses how countries are engaging with digital production technologies, through imports and exports.

Each of these layers is measured through specific indicators, allowing for a comprehensive assessment of a country's digital readiness, which will be discussed in the upcoming sections.

2.1.1 Enabling Infrastructure

2.1.1.1 Energy availability

This indicator measures the availability of electrical energy in a country. Large-scale electrical energy coverage is essential for digitalization, as most digital machines and equipment rely on continuous energy supply to operate properly. Industrialization and digitalization both depend on the availability of electricity. Please note that while the ideal measure is the amount of per capita electricity generated each year, data availability and coverage are much higher for electricity consumption, which is an adequate proxy.

$$Energy\ availability = \frac{Electric\ power\ consumption}{Total\ population}$$

2.1.1.2 Access to digital connectivity

This indicator measures access to broadband connectivity in the country. An intensification of digitalization requires widespread access to wired broadband internet connectivity as an essential enabling factor.

$$Digital\ connectivity\ (wired) = \frac{Fixed\ broadband\ subscription}{100\ population}$$

2.1.1.3 Quality of connectivity

This indicator measures the quality of the country’s internet connectivity. Digital technologies, especially the more advanced ones (IoT, AI, cyber-physical systems) require high-speed, low-latency, reliable internet connectivity. The indicator is measured by the mean download in megabits per second (Mbps). It is a measure of internet bandwidth, which represents the download rate of a given internet connection.

2.1.2 Production Capabilities

2.1.2.1 Productive investments

Building up pre-existing capabilities needed to engage with higher levels of sophistication involves higher investments in plants, machinery, equipment, etc. Economists capture this through gross fixed capital formation (GFCF). The share of investments relative to manufacturing in total GFCF is a proxy for investments for upgrading the manufacturing structure, such as the establishment of a new plant, the purchase of new production lines, machinery and equipment. The aim is to capture specific investments in production technologies.

$$Productive\ investments\ = \frac{Total\ GCFC}{GDP}$$

2.1.2.2 Productive skills

This indicator measures the mean years of schooling, providing a quantitative picture of the average number of years people spend in school. The indicator is measured as the average number of completed years of education of a country's population aged 25 years and older, excluding years spent repeating individual grades.

$$Productive\ skills = \frac{Years\ of\ schooling\ completed\ by\ the\ population}{Total\ population}$$

2.1.2.3 Operational efficiency

ISO 9001 is the international standard that specifies the requirements for a quality management system, which only firms that possess solid productive and organizational capabilities can obtain. It is a key requirement for access to international customers with high quality standards. This indicator is measured by taking the number of ISO 9001 certificates per 1,000 population.

$$Operational\ efficiency\ = \frac{\#ISO\ 9001\ certificates}{1000\ population}$$

If the investment in GFCF is an essential step towards capital accumulation and industrialization, the next level of analysis is represented by an indicator that captures a certain degree of firms' organizational capabilities. The number of ISO 9001 certificates (measured for a 1,000 population) is such an indicator, as it provides information on how many firms can meet an internationally recognized quality management standard.

2.1.2.4 Technology absorption

This indicator captures the extent to which firms' production processes use technologies developed abroad, which is a useful proxy for firms' level of technological capabilities. The indicator is measured by taking the charges incurred for the use of intellectual property—payments in current US$—adjusting them to GDP to allow for comparisons across countries, while taking differences in the size of their economies into account.

$$Technology\ absorption\ = \frac{Charges\ for\ the\ use\ of\ intellectual\ properties}{GDP}$$

Please note that while this indicator is a useful proxy of technology absorption, especially considering that most low- and lower middle-income countries rely on imports and the use of foreign technology to upgrade their productive capabilities, it does not consider the development of indigenous technology and the use thereof.

2.1.3 Innovation Capabilities

2.1.3.1 Advanced skills

This indicator captures the population's participation rate in tertiary education of a country. Its relevance for digitalization lies in the fact that a broad base of university-level knowledge is needed for the absorption, diffusion and development of advanced digital technologies. This includes not only technical skills, but also knowledge of business management, foreign languages, laws and regulations, etc. The indicator is measured by the gross enrolment ratio of the official school age population for tertiary education (both sexes). This is calculated by the number of students enrolled in tertiary education, expressed as a percentage of the population of the official age for tertiary education (the 5-year age group immediately following upper secondary education).

$$\text{Advanced skills} = \frac{\#\text{Students enrolled in tertiary education}}{\text{Population in the 5 year age group immediately following upper secondary education}}$$

Please note that this is the gross enrolment ratio, which counts the total number of students enrolled in tertiary education. It includes overaged students, e.g. due to repetition of grades or other inefficiencies in the education system. The gross ratio thus measures the overall level of participation in tertiary education of students of all ages, and not the education system's 'efficiency' in educating students at the appropriate age.

2.1.3.2 Specialized skills

This indicator measures the level of specialization of a country's tertiary education system to the specific skills needed for digitalization, namely science, technology, engineering and mathematics (STEM). Although digitalization requires a high level of skills across many different areas, these are the core specialized skills required, which are usually in short supply in the world. This indicator is measured by the percentage of STEM graduates in tertiary education.

$$\%\text{Graduates from STEM programmes in tertiary education} = \frac{\text{Graduates from STEM programmes}}{\text{Total graduates}}$$

2.1.3.3 Research effort

This indicator measures a country's total R&D effort. A large investment in R&D indicates the existence of capabilities to carry out research and innovation, which are crucial for digitalization. This indicator is measured by gross expenditure in R&D (public and private) as a share of GDP.

$$Research\ effort\ = \frac{Gross\ expenditure\ in\ R\&D}{GDP}$$

Gross expenditure in R&D as a share of GDP is an indicator of a country's research effort. It measures both public and private investments in R&D and compares the to the size of the country's economy (GDP). While innovation may also take place without R&D, modern industries increasingly require dedicated labs and facilities for the development of new technologies, components and products. Thus, it is a useful indicator of a country's overall innovation.

2.1.3.4 Research output

This indicator measures the production of academic articles by the country's scientists and technicians. It captures the quality of the research conducted in the country, which can have an important impact on digitalization both directly through research in areas related to digital technologies, or indirectly by creating innovation capabilities. This indicator is measured by the number of scientific and technical journal articles per million people.

$$Research\ output = \frac{\#Scientific\ \&\ technical\ journal\ articles\ published}{Total\ population} \times\ 1\ million$$

2.1.3.5 Innovation output (patents)

This indicator measures a country's innovation output potential based on the number of patents in force in the country, i.e. the patents granted to both domestic and foreign firms established in the country. Patents are a common measure of a country's level of innovativeness, as it is the formal way of protecting innovations. A high number of patents in a country thus indicates a high level of innovation capabilities, which are essential for absorbing and developing digital technologies. This indicator is measured by the total number of patents in force per USD 100 billion GDP.

$$Innovation\ output\ (patents) = \frac{Total\ patents\ in\ force}{GDP} \times 100\ billion$$

2.1.3.6 Innovation output (royalties)

This indicator measures a country's innovation output based on its intellectual property rights (IPR) receipts. As a country becomes more technologically advanced, it starts licensing and exporting its technologies to other countries that pay royalties for them. This indicator measures how technologically advanced a country is, which is a useful proxy of how capable the country is in terms of absorbing and developing digital technologies. This indicator is measured by the value of IPR receipts per US$ 1,000 of GDP per capita.

$$Innovation\ output\ (royalties) = \frac{IPR\ receipts}{GDP}$$

2.1.4 Digital Capabilities

2.1.4.1 Imports of digital production technologies, parts and instruments

This indicator measures imports of ADP (advanced digital production) technologies as an aggregate value of production technology, parts or components and technology instrumentations. As a country's digital capabilities are upgraded and it starts to engage with fully fledged digital production technologies, it needs to import such technologies and adapt them for deployment in its local production system. The learning process countries must embark on to be able to engage in digital manufacturing entails a period of importing more sophisticated technologies that are likely to be produced in advanced and fast industrializing economies. This indicator is built as a ratio between digital production technologies (i.e. the digital classification which consists of 127 product classes shown in Annex 1) and GDP.

$$Imports\ of\ ADP = \frac{Imports\ of\ digital\ products}{GDP}$$

2.1.4.2 Exports of digital production technologies, parts and instruments

Differently from the import indicators above, this indicator measures the country's competitiveness in digital technologies by measuring its exports of these products. It is assumed that if the country exports these products, it possesses digital-related capabilities. This indicator still provides interesting insights into a country's capabilities and potential for digitalization.

$$Exports\ of\ ADP = \frac{Exports\ of\ digital\ products}{GDP}$$

2.1.4.3 Imports of computer and information services

One important consideration is the use and provision of digital services. This is particularly relevant for digitalization because many digital technologies need digital services to operate or will only provide benefits if they are used in conjunction with digital services (such as software engineering services to interconnect objects, data analytics services such as business intelligence, data processing and storage services such as cloud computing, etc.). Imports of computer and information services (CIS) is directly related to digitalization as it includes hardware and software-related services, data processing services and database services. These services are essential for the functioning of digitalized production, so a country with a high level of imports of such services demonstrates active engagement with digital technologies.

$$Imports\ of\ CIS = \frac{Imports\ of\ CIS}{GDP}$$

2.1.4.4 Exports of computer and information services

Exports of CIS play a critical role in the global economy, as they represent a country's ability to provide essential digital services to international markets. By exporting these services, countries can capitalize on their technological expertise, boost their economies, and enhance their global competitiveness. Additionally, the export of digital services supports global digitalization efforts, enabling businesses worldwide to implement and benefit from advanced technologies. Countries that excel in exporting computer and information services not only generate significant revenue but also establish themselves as key players in the digital transformation landscape.

$$Exports\ of\ CIS\ = \frac{Exports\ of\ CIS}{GDP}$$

2.2 Digital Readiness Heatmap

Building on the collected data on digital readiness levels, the Digital Readiness Heatmap provides a comprehensive visual representation of the current digital capabilities of countries across the Danube region. The heatmaps, provided as supplementary material in the Danube DNA Google Drive, are presented in both table form and as interactive geomaps. These geomaps allow users to filter data by indicator and year, enabling direct comparisons of countries' performance within a geographical context. As the geomaps function exclusively within Google Drive, we have included several screenshots for reference at the end of this chapter to ensure accessibility for all users.

The heatmaps leverage key indicators outlined in Section 1.1, benchmarking countries' performance against percentile-based thresholds. This dual representation—both table-based and map-based—highlights strengths, identifies average performance, and pinpoints areas requiring improvement. By offering a versatile and interactive tool, the heatmaps support stakeholders in identifying digital gaps and opportunities for targeted strategic action.

2.2.1 Data Gathering and Availability

First, all indicators and available years for EU27 countries were gathered into an Excel table. The main heatmap reflects the most recent available year for each indicator, with the majority reflecting the year 2022. The 2015 heatmap primarily includes data from 2015, except for the indicators "Imports of digital products as a share of GDP," "Exports of digital products as a share of GDP" and "Mean download speed (Mbps)", for which data are not available. The absence of data for these digital product indicators is due to their reliance on the Harmonized System (HS) classification of 2017, one of the most widely adopted international systems for classifying traded products (Wikipedia contributors, 2024). Consequently, data for these indicators are also unavailable for the year 2010. For additional information regarding indicator availability, please refer to Annex 2 and for the details on data sources, please refer to the

Digital Readiness Assessment Excel file, which is provided in the Danube DNA Google Drive Folder.

It is important to note that data availability across the project countries is neither comprehensive nor consistent. Gaps in data coverage and variations in availability across years and indicators limit the scope for creating a fully uniform and comparable dataset. In some cases, specific indicators are not available for certain countries:

- In Malta, data for "Mean Years of Schooling" are not available.
- The "Percentage of Graduates from STEM Programs in Tertiary Education (%)" is missing for Germany, France, Italy, Luxembourg, and Poland in 2010, as well as for Greece and the Netherlands in 2015.
- In Cyprus, data for "Intellectual Property Right Payments (Royalties) (current US$ per GDP)" are missing for both 2015 and 2010.
- Additionally, Cyprus does not have data for the "Exports of Digital Products as a Share of GDP" for 2022 and 2017.
- The "Deployment and Adaptation of Computer and Information Services" indicator is missing for several countries: Cyprus, Hungary, and Ireland in 2010; Lithuania in 2015; Luxembourg in 2022 and 2015; Portugal in 2022 and 2010; the Netherlands in 2022 and 2015; Romania in 2010; and Slovenia and Spain have no data available for any year.
- The "Exports of Computer and Information Services as a Share of GDP" indicator is unavailable for Hungary and Ireland in 2010; Luxembourg in 2022 and 2015; Malta in 2015; the Netherlands in 2010; Portugal in 2022 and 2010; Romania in 2010; and once again, Slovenia and Spain have no data available for this indicator across all years.

Additionally, for the two non-EU27 partners in the Danube region, Bosnia and Herzegovina and Montenegro:

- Data for "Imports of Computer and Information Services as a Share of GDP" and "Exports of Computer and Information Services as a Share of GDP" are not available for Bosnia and Herzegovina in 2022. The share of Gross Fixed Capital Formation in Gross Domestic Product (GDP) (%) is not available for Bosnia and Herzegovina; however, data for 2021 is available and has been used instead.
- None of the data for "Percentage of Graduates from STEM Programs in Tertiary Education (%)" is available for Montenegro.

- In 2010, Bosnia and Herzegovina lacks data for "Percentage of Graduates from STEM Programs in Tertiary Education (%)", "Gross Expenditure in R&D (GDP) (%)", and "Exports of Computer and Information Services as a Share of GDP."
- Montenegro also does not have data for "Gross Expenditure in R&D (GDP) (%)" in 2010.

2.2.2 Color Coding

After collecting indicator values for all EU27 countries, the heatmap's color coding was determined through a systematic process based on the 25th and 75th percentile values, designed specifically for benchmarking purposes. The percentile values were calculated using Excel's "PERCENTILE.EXC" function. This function returns the k-th percentile of values in a range, where *k* is between 0 and 1, exclusive. The calculation method is outlined in the equation below.

$$\text{PERCENTILE.EXC}(\text{array}, k) = \begin{cases} \text{\#NUM!} & \text{if array is empty} \\ \text{\#VALUE!} & \text{if } k \text{ is nonnumeric} \\ \text{\#NUM!} & \text{if } k \leq \dfrac{1}{n+1} \text{ or } k \geq \dfrac{n}{n+1} \\ \text{Interpolated Value} & \text{if } (k \times (n+1)) \text{ is not an integer and can be interpolated} \\ \text{Exact Value} & \text{if } (k \times (n+1)) \text{ is an integer} \end{cases}$$

For the dataset covering all 27 EU countries, the percentiles were computed to identify specific benchmark thresholds:

- The 25th percentile represents the value of the 7th-ranked country, determined by the equation below. This percentile serves as a benchmark for identifying countries that fall within the lower quartile of performance.

$$25th\ percentile = (27 + 1) \times \frac{1}{4} = 7$$

- The 75th percentile corresponds to the value of the 21st-ranked country, calculated by the equation below. This percentile serves as a benchmark for identifying countries within the upper quartile of performance.

$$75th\ percentile = (27 + 1)\ x\ \frac{3}{4} = 21$$

Since complete data was not available for all indicators, the "PERCENTILE.EXC" function employs linear interpolation to estimate missing values, which can be seen in the equation below. For example, to determine the 25th percentile, interpolation may occur between the values of the 6th and 7th countries or between the 7th and 8th countries, depending on the data available.

$$\text{Interpolated Value} = (1 - d) \cdot \text{array}[i] + d \cdot \text{array}[i + 1]$$

- **array** is the data set.
- **k** is the percentile to be computed.
- **n** is the number of elements in the array.

$$\big(k \times (n + 1)\big) = i + d \text{ where } i \text{ is the integer part and } d \text{ is the fractional part.}$$

- **array[i]** and **array[$i + 1$]** are the elements in the array at the ith and $i + 1$th positions respectively after sorting the array.

The color coding in the heatmap is directly tied to these percentile-based benchmarks. The formatting is applied as follows:

- Green is applied to values greater than (but not equal to) the 75th percentile, indicating performance that is above the upper quartile benchmark. Countries highlighted in green are considered to be high performers relative to their peers.
- Red is applied to values less than (but not equal to) the 25th percentile, indicating performance below the lower quartile benchmark. Countries highlighted in red are considered to be low performers.
- Yellow is applied to values that fall between the 25th and 75th percentiles, indicating performance that is within the median range. These countries are considered to have average performance relative to the established benchmarks.

2.2.3 Exemplary Visualizations of Digital Readiness

In this subsection, we present exemplary screenshots of the heatmaps and geomaps derived from the Digital Readiness Assessment Excel sheet. These visuals illustrate the key data and insights discussed earlier, showcasing both the tabular heatmap format and the geographical geomap representation. While the interactive geomap feature is accessible through the Danube DNA Google Drive, the following screenshots provide a static reference for users, highlighting how the tool visualizes digital readiness levels across the Danube region. These examples demonstrate how filtering by indicator and year enables targeted comparisons between countries, offering valuable insights into regional digital capabilities.

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Layer	Indicator	Measure	Year	Austria	Bosnia and Herzegovina	Bulgaria	Croatia	Czech Republic	Germany	Hungary	Montenegro	Romania	Serbia	Slovakia	Slovenia
Enabling Infrastructure	Energy availability	Electricity consumption per capita (MWh / person)	2022	8.25	3.81	5.26	4.48	6.35	6.40	4.65	5.01	2.90	5.03	4.66	6.75
	Access to digital connectivity	Fixed broadband subscriptions (number per 100 people)	2022	29	27	35	27	38	45	35	31	32	26	33	32
	Quality of connectivity	Mean download speed (Mbps)	2022	45.56	8.16	24.77	20.74	39.15	72.95	42.99	38.65	112.39	51.84	21.19	38.15
Production Capabilities	Productive investments	Share of Gross Fixed Capital Formation in Gross Domestic Product (GDP) (%)	2022	25.30%	21.40%	17.06%	19.63%	26.80%	22.09%	28.18%	21.51%	24.94%	24.16%	20.08%	21.62%
	Productive skills	Mean years of schooling (number of years)	2021	12.26	10.54	11.41	12.19	12.87	14.09	12.25	12.18	11.28	11.37	12.91	12.8
	Operational efficiency	ISO 9001 certificates / per 1000 population (number per 1000 people)	2021	0.43	0.29	0.98	0.74	1.13	0.57	0.67	0.26	0.56	0.52	0.71	1.03
	Technology absorption	Intellectual Property Right payments (royalties) (current US$ per GDP)	2022	0.39%	0.06%	0.29%	0.54%	0.56%	0.49%	0.77%	0.11%	0.32%	1.01%	0.64%	0.47%
Innovation Capabilities	Specialised skills	Percentage of graduates from STEM programmes in tertiary education (%)	2021	30.60%	23.96%	19.50%	28.50%	25.90%	35.80%	15.50%		29.10%	30.50%	22.20%	28.60%
	Advanced skills	Gross enrolment ratio in tertiary education (% of total enrollment)	2022	93.90%	43.60%	74.00%	72.30%	69.10%	75.70%	56.50%	56.80%	55.30%	68.70%	50.70%	82.20%
	Research effort	Gross expenditure in R&D (GDP) (%)	2022	3.30%	2.00%	0.80%	1.20%	2.00%	3.10%	1.60%		0.50%	1.00%	0.90%	2.10%
	Research output	Scientific and technical journal articles per million people (number / million people)	2020	1,536	281	594	1,186	1,402	1,315	767	498	504	687	993	1,821
	Innovation output (patents)	Total patents in force per 100 billion USD GDP	2022	24,832	123	2,384	1,043	4,321	30,552	4,263	498	1,105	1,213	2,016	6,177
	Innovation output (royalties)	Intellectual property rights receipts (royalties) (current US$ per GDP)	2022	0.357%	0.027%	0.323%	0.175%	0.285%	1.306%	0.903%	0.015%	0.032%	0.331%	0.045%	0.260%
Digital Capabilities	Deployment and adaptation of digital production technologies	Imports of digital products as a share of GDP	2022	0.003%	0.002%	0.003%	0.002%	0.014%	0.003%	0.009%	0.002%	0.003%	0.003%	0.010%	0.004%
	Industrial competitiveness in digital technologies	Exports of digital products as a share of GDP	2022	0.002%	0.000%	0.002%	0.001%	0.014%	0.003%	0.007%	0.000%	0.001%	0.001%	0.006%	0.002%
	Deployment and adaptation of computer and information services	Imports of computer and information services as a share of GDP	2022	2.052%		0.757%	0.943%	1.327%	0.315%	1.329%	1.485%	1.315%	0.987%	1.063%	
	Industrial competitiveness in computer and information services	Exports of computer and information services as a share of GDP	2022	2.139%		3.346%	2.138%	2.372%	0.372%	1.758%	3.055%	3.266%	4.236%	1.685%	

Figure 1: Heat Map 2022

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Layer	Indicator	Measure	Year	Austria	Bosnia and Herzegovina	Bulgaria	Croatia	Czech Republic	Germany	Hungary	Montenegro	Romania	Serbia	Slovakia	Slovenia
Enabling Infrastructure	Energy availability	Electricity consumption per capita (MWh / person)	2015	8.33	3.43	4.86	3.90	6.38	7.03	4.10	4.73	2.65	4.54	5.15	6.88
	Access to digital connectivity	Fixed broadband subscriptions (number per 100 people)	2015	28	18	22	23	28	37	28	18	21	19	23	27
	Quality of connectivity	Mean download speed (Mbps)	2017	15.26	7	17.54	12.57	17.31	18.8	23.16	5.85	21.33	12.25	18.85	18.37
Production Capabilities	Productive investments	Share of Gross Fixed Capital Formation in Gross Domestic Product (GDP) (%)	2015	22.70%	20.87%	20.86%	19.23%	26.54%	20.02%	22.17%	20.15%	24.95%	16.97%	23.68%	18.65%
	Productive skills	Mean years of schooling (number of years)	2015	12.08	9.29	11.19	11.66	12.67	14.08	11.85	11.72	10.98	11.02	12.64	12.57
	Operational efficiency	ISO 9001 certificates / per 1000 population (number per 1000 people)	2015	0.52	0.22	0.76	0.60	1.01	0.65	0.59	0.14	1.04	0.35	1.05	0.72
	Technology absorption	Intellectual Property Right payments (royalties) (current US$ per GDP)	2015	0.38%	0.06%	0.37%	0.53%	0.65%	0.30%	1.60%	0.08%	0.47%	0.45%	0.59%	0.51%
Innovation Capabilities	Specialised skills	Percentage of graduates from STEM programmes in tertiary education (%)	2015	29.27%	16.98%	20.79%	23.86%	23.17%	36.74%	22.07%		28.35%	25.88%	21.14%	25.65%
	Advanced skills	Gross enrolment ratio in tertiary education (% of total enrollment)	2015	82.30%	48.60%	74.00%	66.20%	67.20%	68.20%	50.10%	60.30%	49.40%	57.90%	52.70%	82.20%
	Research effort	Gross expenditure in R&D (GDP) (%)	2015	3.00%	0.20%	0.90%	0.80%	1.90%	2.90%	1.30%	0.40%	0.50%	0.80%	1.20%	2.20%
	Research output	Scientific and technical journal articles per million people (number / million people)	2015	1,486	161	352	970	1,544	1,302	663	364	518	690	917	1,721
	Innovation output (patents)	Total patents in force per 100 billion USD GDP	2015	9,161	134	893	975	1,290	15,092	2,425	173	951	1,145	463	2,972
	Innovation output (royalties)	Intellectual property rights receipts (royalties) (current US$ per GDP)	2015	0.275%	0.079%	0.098%	0.089%	0.247%	0.717%	1.251%	0.019%	0.051%	0.114%	0.030%	0.135%
Digital Capabilities	Deployment and adaptation of digital production technologies	Imports of digital products as a share of GDP	2017	0.002%	0.002%	0.003%	0.002%	0.011%	0.003%	0.009%	0.002%	0.003%	0.002%	0.013%	0.003%
	Industrial competitiveness in digital technologies	Exports of digital products as a share of GDP	2017	0.002%	0.000%	0.002%	0.001%	0.011%	0.003%	0.008%	0.000%	0.002%	0.000%	0.009%	0.002%
	Deployment and adaptation of computer and information services	Imports of computer and information services as a share of GDP	2015	0.923%	0.044%	0.453%	0.509%	0.699%	1.041%	1.050%	0.766%	0.498%	0.490%	0.670%	
	Industrial competitiveness in computer and information services	Exports of computer and information services as a share of GDP	2015	1.263%	0.216%	1.473%	0.849%	1.216%	0.814%	1.330%	0.219%	1.353%	1.287%	0.624%	

Figure 2: Heatmap 2015

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Layer	Indicator	Measure	Year	Austria	Bosnia and Herzegovina	Bulgaria	Croatia	Czech Republic	Germany	Hungary	Montenegro	Romania	Serbia	Slovakia	Slovenia
Enabling Infrastructure	Energy availability	Electricity consumption per capita (MWh / person)	2010	8.40	3.07	4.56	3.92	6.32	7.40	3.88	5.42	2.55	4.36	5.16	6.51
	Access to digital connectivity	Fixed broadband subscriptions (number per 100 people)	2010	25	10	15	19	22	32	22	10	15	12	16	23
	Quality of connectivity	Mean download speed (Mbps)													
Production Capabilities	Productive investments	Share of Gross Fixed Capital Formation in Gross Domestic Product (GDP) (%)	2010	21.60%	20.76%	22.18%	20.88%	27.15%	19.54%	20.07%	21.64%	25.67%	17.68%	21.02%	21.08%
	Productive skills	Mean years of schooling (number of years)	2010	11.72	7.11	10.72	11.02	12.39	13.85	11.88	11.18	10.73	10.37	12.27	12.06
	Operational efficiency	ISO 9001 certificates / per 1000 population (number per 1000 people)	2010	0.62	0.25	0.84	0.49	1.55	0.62	0.81	0.14	0.80	0.25	0.72	0.83
	Technology absorption	Intellectual Property Right payments (royalties) (current US$ per GDP) (%)	2010	0.41%	0.03%	0.23%	0.38%	0.45%	0.21%	1.36%	0.21%	0.26%	0.37%	0.18%	0.71%
Innovation Capabilities	Specialised skills	Percentage of graduates from STEM programmes in tertiary education (%)	2010	30.86%		20.84%	20.40%	24.10%		18.07%		17.87%	24.49%	21.22%	22.09%
	Advanced skills	Gross enrolment ratio in tertiary education (% of total enrollment)	2010	75.00%	37.20%	58.40%	57.10%	64.90.%		60.70%	52.70%	75.20%	48.50%	58.00%	90.30%
	Research effort	Gross expenditure in R&D (GDP) (%)	2010	2.70%		0.60%	0.70%	1.30%	2.70%	1.10.%		0.40%	0.70%	0.60%	2.10%
	Research output	Scientific and technical journal articles per million people (number / million people)	2010	1,322	130	348	924	1,176	1,189	589	175	488	559	660	1,552
	Innovation output (patents)	Total patents in force per 100 billion USD GDP	2010	5,526	833	1,304	1,142	559	10,589	1,655	193	1,189	942	286	4,267
	Innovation output (royalties)	Intellectual property rights receipts (royalties) (current US$ per GDP)	2010	0.24%	0.09%	0.04%	0.05%	0.12%	0.24%	1.55%	0.08%	0.27%	0.09%	0.05%	0.08%
Digital Capabilities	Deployment and adaptation of digital production technologies	Imports of digital products as a share of GDP													
	Industrial competitiveness in digital technologies	Exports of digital products as a share of GDP													
	Deployment and adaptation of computer and information services	Imports of computer and information services as a share of GDP	2010	0.41%	0.06%	0.36%	0.34%	0.61%	2.21%		0.51%		0.43%	0.27%	
	Industrial competitiveness in computer and information services	Exports of computer and information services as a share of GDP	2010	0.52%		0.76%	0.36%	0.62%	1.74%		0.09%		0.40%	0.38%	

Figure 3: Heat Map 2010

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Indicator: Energy availability
2015

Country	Value
Austria	8.33
Bulgaria	4.86
Croatia	3.90
Czech Republic	6.38
Germany	7.03
Hungary	4.10
Romania	2.65
Slovakia	5.15
Slovenia	6.88
Bosnia and Herzegovina	3.43
Montenegro	4.73
Serbia	4.54

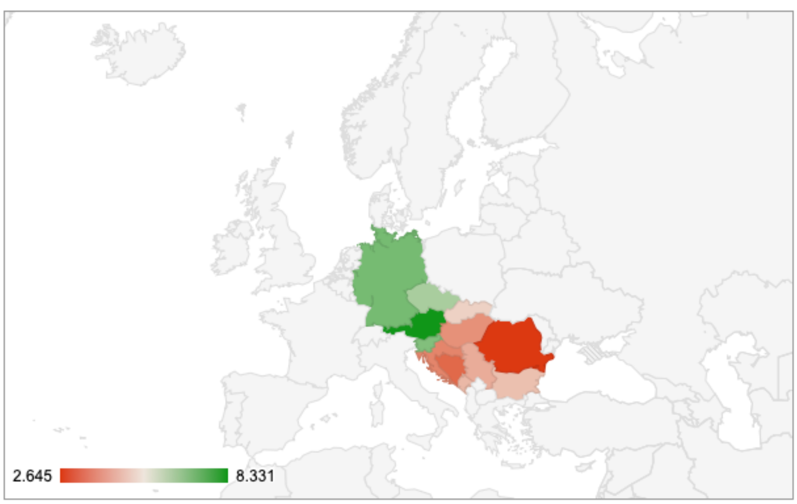

Figure 4: Geomap on Energy Availability, 2015

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Indicator: Operational efficiency

2010

Country	Value
Austria	0.62
Bulgaria	0.84
Croatia	0.49
Czech Republic	1.55
Germany	0.62
Hungary	0.81
Romania	0.80
Slovakia	0.72
Slovenia	0.83
Bosnia and Herzegovina	0.25
Montenegro	0.14
Serbia	0.25

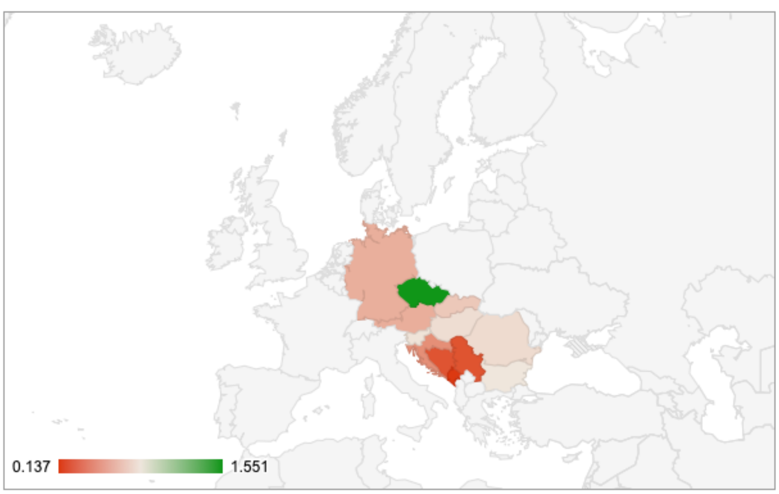

Figure 5: Geomap on Operational Efficiency, 2010

3. Conclusion

The insights gathered through this report offer a detailed examination of the digital readiness and Smart Specialization Strategy (S3) across the Danube Region, underpinned by quantitative analysis and the application of UNIDO's EquIP tool. This dual-layered approach provided a robust evaluation of foundational capabilities, innovation metrics, and digital adoption trends.

Key findings from the quantitative analysis reveal critical strengths in digital infrastructure and innovation ecosystems in countries like Austria, Germany, and Slovenia, which demonstrate leadership in areas such as advanced manufacturing and digitalization. The EquIP tool's structured evaluation further highlighted gaps in governance, digital capabilities, and innovation readiness across less-developed regions, with significant potential for strategic growth.

The **Digital Readiness Heatmap**, developed as part of this assessment, serves as a powerful visual tool for identifying regional disparities and benchmarking country-level performance. The analysis pointed to specific opportunities to enhance digital adoption through targeted investments in enabling infrastructure, production capabilities, and STEM-focused education.

Moreover, the quantitative framework emphasizes the critical role of tailored, sector-specific strategies. For example, the focus on tourism and agriculture in Croatia and Montenegro aligns with their unique competitive advantages, while Austria's and Germany's emphasis on Industry 4.0 technologies showcases their commitment to sustaining global competitiveness.

This report underscores the necessity of leveraging the EquIP tool and other data-driven methods for continuous monitoring and policy refinement. These tools not only enhance the precision of regional development initiatives but also ensure alignment with the overarching objectives of sustainable and inclusive growth.

Looking forward, the Danube region must prioritize investments in digital capabilities, foster stronger collaboration between academia, industry, and government, and actively address workforce skill gaps. Such efforts are vital for enabling all regions, irrespective of their current readiness levels, to fully realize their digital and economic potential.

By integrating these insights and recommendations, stakeholders can accelerate the region's transformation into a digitally robust and innovation-driven economy.

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Annex 1 – Classification of Digital Production Technologies by Type

Type DPT	HS 2017 6-Digits	BEC 4	Description
Final Good	842320,842330,842381, 842382,842389,842390, 844331,844332,845611, 845612,845690,845811, 845891,845921,845931, 845941,845951,845961, 846012,846022,846023, 846024,846031,846221, 846241,846520,847130, 847141,847149,847150, 847160,847170,847180, 847190,847780,847950, 848610,848620,848630, 848640,851521,851531, 851580,851712,851761, 851762,851769,852190, 852352,852692,852852, 852862,854290	41	Various final goods including scales, machinery, and data-processing machines.
Parts	847330,847790,848690, 851770,852351,852990, 853331,853339,853340, 853390,854040,854089, 854121,854129,854140, 854150,854190,854231, 854232,854233,854239	42	Parts and accessories for various digital production machinery.
Instruments	901210,901290,901380, 901390,901520,901540, 901580,901590,901600,	41, 42	Various instruments, including surveying instruments,

	901730,902219,902229, 902410,902480,902490, 902580,902590,902610, 902620,902680,902690, 902710,902720,902730, 902750,902780,902790, 902810,902820,902830, 902890,902910,902920, 902990,903010,903031, 903032,903033,903039, 903040,903082,903084, 903089,903090,903141, 903149,903180,903190, 903210,903220,903281, 903289,903290	measuring devices, and parts thereof.

Note. The data is from Unveiling structure and dynamics of global digital production technology networks: A new digital technology classification and network analysis based on trade data by Andreoni et.al., 2023 https://www.soas.ac.uk/sites/default/files/2023-12/economics-wp261.pdf. Copyright 2023 by *SOAS University of London*

Annex 2 - Data Availability per each Indicator

Indicator	2010	2015	2022
Electricity consumption per capita (MWh / person)	2010	2015	2022
Fixed broadband subscriptions (number per 100 people)	2010	2015	2022
Mean download speed (Mbps)	N/A	2017	2022
Share of Gross Fixed Capital Formation in Gross Domestic Product (GDP) (%)	2010	2015	2022
Mean years of schooling (number of years)	2010	2015	2021
ISO 9001 certificates / per 1000 population (number per 1000 people)	2010	2015	2021
Intellectual Property Right payments (royalties) (current US$ per GDP)	2010	2015	2022

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Percentage of graduates from STEM programmes in tertiary education (%)	2010	2015	2021
Gross enrolment ratio in tertiary education (% of total enrollment)	2010	2015	2022
Gross expenditure in R&D (GDP) (%)	2010	2015	2022
Scientific and technical journal articles per million people (number / million people)	2010	2015	2020
Total patents in force per 100 billion USD GDP	2010	2015	2022
Intellectual property rights receipts (royalties) (current US$ per GDP)	2010	2015	2022
Imports of digital products as a share of GDP	N/A	2017	2022

Exports of digital products as a share of GDP	N/A	2017	2022
Imports of computer and information services as a share of GDP	2010	2015	2022
Exports of computer and information services as a share of GDP	2010	2015	2022