

## Configurational analysis of digital transformation profiles across European countries

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**Abstract.** Digital transformation has become an important determinant of economic development, while countries follow different structural pathways toward digital maturity. This study aims to identify digital transformation profiles of European countries using an author-developed configurational analysis framework that integrates structural economic and digital characteristics. The proposed methodology combines Min–Max normalization, aggregation of economic and digital indicators, construction of the High Digital Sector Transformation (HDST) index, fuzzy-set calibration, an original configurational profiling procedure, and profile stability assessment. Based on structural sectoral

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characteristics, digital infrastructure, digital governance, and innovation capacity, six digital transformation profiles were identified: Digital Service Economy, Innovation Industrial, Government-led Digitalization, Emerging Digital Economy, Knowledge-driven Economy, and Mixed Model. The findings demonstrate that countries with similar HDST levels may exhibit substantially different structural configurations, indicating the existence of multiple digital transformation pathways. The proposed configurational analysis identified recurring combinations of economic and digital characteristics associated with high levels of digital transformation, while the profiling procedure revealed stable development patterns throughout the study period. The proposed framework extends conventional composite-index approaches by integrating configurational analysis with profile identification and can support comparative assessment of national digital transformation models and evidence-based digital policy design.

**Keywords:** configurational analysis, digital transformation profiles, high digital sector transformation, digital economy, European countries.

**JEL Classification:** O33, C38, L86

## 1. INTRODUCTION

The expansion of the digital economy has altered the global macroeconomic landscape, redefining the mechanisms through which nation-states foster long-term competitiveness and structural growth. Rather than representing a localized technological trend, this digital transition constitutes a systemic reorientation of national economic structures, supported by substantial public capital allocation. Specifically, under the European Union's NextGenerationEU recovery framework, 26% of the Recovery and Resilience Facility – approximately €150 billion – is allocated to digital transformation initiatives (European Commission, 2022). Despite these unprecedented funding levels, national digital development remains highly heterogeneous. While digitalization is theoretically expected to drive labour productivity and structural growth, the frequent occurrence of sub-optimal outcomes in complex digital transformation initiatives underscores the critical socio-economic importance of identifying viable, systemic integration pathways.

To evaluate national progress, macroeconomic literature relies heavily on standardized composite indices, such as the Digital Economy and Society Index (DESI), to examine correlations between digital capabilities, real GDP growth, and public sector efficiency. However, classical econometric models frequently exhibit a notable conceptual limitation: they assume a linear, symmetrical trajectory of digital advancement. This paradigm presumes that individual digital inputs yield proportional, isolated improvements in economic output, thereby disregarding the interdependent structural complexities of national economies. This methodological gap has generated a critical academic debate, contrasting traditional linear estimation with socio-technical systems frameworks that conceptualize digitalization as an emergent, multidimensional phenomenon driven by configuration-specific institutional and structural assets.

This study employs a configurational framework that integrates structural economic characteristics with digital, institutional, and innovation dimensions. Rather than aggregating diverse national attributes into a static, unidimensional index, this approach examines how primary macroeconomic sectors (agriculture, industry, services, and the knowledge economy) interact with digital infrastructure, public

governance, and innovation capacity. This research shifts the analytical focus toward dynamic, structural typologies, providing a robust diagnostic tool for academic researchers and macroeconomic policymakers.

## 2. LITERATURE REVIEW

The digital transformation of European economies represents a systemic structural reorientation that reshapes traditional industrial and societal boundaries while establishing novel digital pathways across the continent. Instead of presenting a uniform trajectory, this evolution is characterized by heterogeneous levels of digital readiness, deep-seated structural determinants, and notable intra-regional disparities among European Union member states (Brodny & Tutak, 2023; Valaskova et al., 2025). To understand these shifting dynamics, research increasingly focuses on mapping regional digital divides and evaluating the restructuring of global value creation, particularly within knowledge-driven tertiary and quaternary sectors (Glebova et al., 2023).

Given that traditional linear models frequently fail to capture the complex, multidimensional interactions defining digital maturity, there is an academic necessity to shift toward set-theoretic configurational paradigms (Mattke et al., 2022). Analyzing digital transformation through a configurational lens allows scholars to identify non-linear pathways and equifinal combinations of technological, organizational, and environmental factors that yield optimal developmental outcomes (Hossain et al, 2025; Hu et al., 2026; Tan & Shu, 2026; Vasa et al., 2023). This methodological approach is particularly valuable when analyzing how diverse institutional environments adopt complex technologies and interoperability frameworks across multiple jurisdictions (Taylor, 2026).

Public administration and national governments in Europe represent critical domains for structural change, where algorithmic governance and digital reforms are actively negotiated (Androniceanu & Streimikiene, 2026; Dinu et al., 2026). The level of digital maturity within these public institutions serves as a fundamental determinant of systemic resilience, economic growth, and administrative efficiency (Bartuseviciene & Butkus, 2024; Ortina et al., 2023; Ravšelj et al., 2026). Consequently, the effective deployment of e-government and GovTech models serves as a primary mechanism for enhancing social progress, institutional trust, and public welfare, aligning public sector management with sustainable development goals (Kuzior et al., 2026; Sira & Kuzior, 2025; Vasylieva et al., 2026).

A key determinant of modern governance profiles is the integration of artificial intelligence and algorithmic readiness into the public sector (Ingaldi & Ulewicz, 2025; Spivakovskyy et al., 2026). However, the rapid expansion of these cognitive systems introduces substantial security vulnerabilities, ranging from generative AI risks to complex socio-technical threats (Wach et al., 2023; Yarovenko et al., 2025). Mitigating these digital hazards requires robust governance frameworks capable of curbing financial crimes and ensuring administrative transparency (Lygina et al., 2026; Yefimenko et al., 2025). At the individual and societal levels, these systemic shifts are further complicated by gendered digital harms, cyberpsychological distress, and broader questions surrounding the political economy of public benefit (Agyare, 2025; Burrell, 2026; Kafoe et al., 2026).

The socio-economic impacts of digital transformation also extend to financial inclusion and the modernization of regulatory frameworks, such as digital taxation mechanisms (Rados Bajlo et al., 2026; Laskienė et al., 2026). For small and medium enterprises (SMEs) and informal business sectors, navigating this transition requires balancing resource constraints against ecosystem opportunities to mitigate market disruptions (Filip et al., 2026; Mtengwane, 2024; Sartamorn et al., 2025). Enterprises increasingly leverage digital marketing and social media channels to establish operational resilience against macroeconomic shocks (Safo-Ankama et al., 2026; Chahdi et al., 2025). Furthermore, these adaptations are closely linked to overall national digital maturity and the relative stability of regional financial structures, particularly through

the expansion of digital banking services and advanced accounting tools (Asare, 2025; Meidute-Kavaliauskiene et al., 2026; Rakhimzhanova et al., 2026).

Importantly, the digital agenda is intrinsically linked to environmental, social, and governance (ESG) performance within the “twin transition” framework (Alodat & Dong, 2026; Dinu et al., 2025; Nguyen et al., 2026). Under this integrated paradigm, digital capabilities act as direct drivers of decarbonization, establishing spatial linkages between technological maturity and carbon reduction (Jiang et al., 2025; Wang et al., 2025). Similarly, a state's energy security is heavily influenced by public readiness for advanced AI, indicating a significant nexus between energy policy and technological capabilities (Kuzior et al., 2025; Mammadov et al., 2025). This technological intersection is also vital for bridging digital innovations with artificial intelligence to promote energy equity and secure systemic energy justice (Kirichok et al., 2025). Supporting these eco-digital systems requires capital markets and public R&D instruments to allocate targeted funding for digital and green energy startups, which are heavily moderated by national levels of economic freedom (Bilan & Halynskyi, 2026; Sitnicki et al., 2026b; Sitnicki et al., 2026c). Moreover, the development of entrepreneurial ecosystems alongside active digitalization serves as a primary driver for the expansion and success of these energy start-ups (Sitnicki et al., 2026a). At the micro-operational level, these technologies are deployed in highly specialized settings, ranging from energy-efficient groundwater pumping upgrades to AI-driven waste management systems (Chmiela et al., 2025; Kajda & Karwot, 2026). Evaluated collectively, these dynamics indicate that AI adoption within EU member states co-determines employment patterns, economic performance, and environmental sustainability (Vărzaru & Bocean, 2026).

The viability of these configurations depends fundamentally on human capital development; however, transition economies and post-socialist institutional systems frequently encounter a “reskilling paradox,” wherein workforce inertia slows down digital public sector transformation (Tagaev & Bilan, 2026b; Zhilkishbayeva et al., 2025). Concurrently, the strategic integration of AI in these transition economies serves as a catalyst for human capital development, highlighting the critical role of adaptive skills in modernizing the workforce (Tagaev & Bilan, 2026a). Cultivating such human resource potential is equally vital in specific welfare sectors, where digital healthcare solutions and investments in medical AI enhance the efficiency of public health expenditures (Hrytsenko et al., 2026; Ndhlovu et al., 2026; Sabyrzhan et al., 2026). These technological adaptations are further shaped by shifting consumer motivations, cultural values, and lifelong learning frameworks, which are increasingly analyzed via digital ethnography to capture deeper socio-cultural insights (Briana & Kostakis, 2025; Oe & Weeks, 2025; Oe et al., 2026).

Additionally, the spatial distribution of digital profiles is closely tied to regional crises, institutional trust, and post-conflict reconstruction needs, particularly within Central and Eastern European contexts where digital governance serves as a pillar for economic resilience (Juhászová et al., 2026; Lyeonov et al., 2026; Topazly et al., 2026). Under conditions of severe geopolitical or economic stress, a country's digital maturity acts as a core stabilizing mechanism that supports economic security and municipal recovery (Tsymbol & Demediuk, 2025; Bartuseviciene et al., 2026). These dynamics highlight the critical need to align digital policies with regional strategies, such as green transition targets in the Baltic states, to ensure balanced regional progression (Streimikiene & Kyriakopoulos, 2025). Ultimately, these digital transitions must remain grounded in fundamental human rights and localized socio-economic realities to prevent the exacerbation of existing inequities (Crowley & Mujtaba, 2026; Mshana & Postrzednik-Lotko, 2026).

In sum, the existing literature demonstrates that digital transformation across European states is a non-linear, complex system shaped by diverse institutional, environmental, and socio-economic frameworks. Consequently, a configurational research design is essential to capture the heterogeneous profiles of member states and uncover the specific configurations of factors driving digital progress. Mapping these multidimensional pathways provides a systematic foundation for tailored, country-specific policy interventions that promote equitable development across the European continent.

Building upon these identified gaps, the primary objective of this study is to conduct a configurational analysis of digital transformation profiles across European countries to identify the non-linear, set-theoretic combinations of technological, organizational, and institutional conditions associated with high digital performance. By mapping these heterogeneous profiles, this research aims to identify the specific causal pathways driving digital progress, thereby providing a systematic foundation for targeted, country-specific policy designs. Ultimately, this study seeks to offer actionable insights that support equitable, sustainable, and balanced digital development across European countries.

### 3. METHODOLOGY

#### 3.1. Data

For the purposes of the study, two datasets were constructed, reflecting, on the one hand, the structural characteristics of national economies and, on the other hand, the level of digital environment development and the institutional prerequisites for digital transformation. This made it possible to profile countries by taking into account the capacity of their key economic sectors to adapt to technological change.

The first dataset is intended to develop a generalized profile of the economic structure of countries by aggregating indicators across the key sectors of the economy. This approach is based on the need to assess not individual industries but rather their role in shaping a country's economic potential and its capacity to embrace digital transformation. Four sectors of the economic structure were selected as the basis. The sectoral indicators were derived from gross value added by economic activity, expressed as a percentage of GDP, using the Eurostat database (Eurostat, n.d.).

The primary sector (AGR) is based on the agriculture, forestry and fishing indicator, which characterizes economic activity in agriculture, forestry, and fisheries. The inclusion of this sector is justified by the fact that the digitalization of agriculture (in particular, the use of precision agriculture technologies, automation of production processes, and digital resource management platforms) is gradually transforming traditional agricultural production models and improving the efficiency of natural resource utilization while preserving the environment.

The industrial sector (IND) is represented by a composite indicator constructed based on the industry, manufacturing, and construction indicators. These components were selected because industry is one of the sectors of the economy most responsive to digital innovation. Manufacturing industries concentrate a significant share of automation processes, the implementation of the Industrial Internet of Things, robotics, and big data analytics. Therefore, assessing the level of industrial sector development is essential for determining a country's potential to transition to digital production models.

The tertiary sector (SERV) relates to the services sector and is represented by a composite indicator that includes wholesale and retail trade, transportation, accommodation and food service activities, real estate activities, financial and insurance activities, as well as public administration, education, healthcare, and social services. Such a broad range of components is justified by the fact that the services sector has become the primary environment for the practical implementation of digital technologies, where their adoption occurs more rapidly than in other sectors and is more responsive to user needs. Financial technologies, e-commerce, digital public services, distance education, and telemedicine are examples of areas in which digital transformation directly affects the quality of economic processes and social interaction.

The quaternary sector (KNOW) relates to the knowledge and information economy and includes information and communication activities, as well as professional, scientific, technical, and administrative service activities. The identification of this block is important because digital transformation is largely based on the development of sectors that generate, disseminate, and utilize knowledge. These activities shape the

innovative capacity of the economy, support the creation of digital solutions, and determine the long-term competitiveness of countries.

The second dataset characterizes the digital prerequisites for the transformation of economic sectors through a system of aggregated digital blocks. Unlike the traditional approach, which assesses digitalization solely in terms of access to technology, this study employs a comprehensive framework that incorporates the infrastructural, institutional, and innovation dimensions of digital development. The measurement framework was constructed using selected indicators from the Network Readiness Index (Portulans Institute, n.d.), which provides internationally comparable measures of countries' digital readiness and the technological, institutional, and innovation factors supporting digital transformation.

The first digital block is digital infrastructure (DIG\_INFRA), which is constructed using indicators of international Internet bandwidth, expenditure on computer software, and the number of secure Internet servers. These indicators were selected because digital transformation is impossible without a fundamental technological infrastructure. International bandwidth reflects the country's level of integration into global digital networks, software expenditure characterizes the intensity of digital tool adoption by organizations, and the number of secure servers serves as an indicator of the reliability of the digital environment and the level of development of electronic transactions.

The second block characterizes digital governance and the institutional environment (DIG\_GOV) and includes indicators of the development of government online services, regulatory quality, citizen e-participation, and the socio-economic divide in the use of digital payments. The inclusion of these indicators is justified by the fact that digital transformation is not only a technological but also an institutional process. Effective digital governance depends on the ability of public institutions to create favorable conditions for the use of digital technologies, ensure the accessibility of digital services, and minimize inequalities in the digital inclusion of the population.

The third block relates to innovation and cybersecurity capacity (INNOV) and includes indicators of government and higher education expenditure on research and development, cybersecurity, and the regulatory environment for information and communication technologies. These indicators were selected because digital transformation requires not only the adoption of existing technologies but also the capacity of the economy to generate its own innovations, ensure the protection of digital assets, and establish a regulatory framework for the development of digital markets.

The empirical basis of the study consists of panel data covering the period 2019–2024 for 31 European countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye, and Ukraine.

### 3.2. Methods

To identify country profiles with regard to the digital transformation of key economic sectors, a methodological approach was developed based on the assumption that the digital transformation of the economy is a complex phenomenon that cannot be adequately assessed using a single composite indicator. It results from the interaction of the structural characteristics of the economy, the level of digital infrastructure development, the quality of digital governance, and innovation capacity.

At the *first stage*, the original data were normalized using Min–Max normalization (1):

$$x_{ij}^* = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)}, \quad (1)$$

where  $x_{ij}^*$  is the normalized value of the  $j$ -th indicator for country  $i$ , and  $x_{ij}$  is the actual value of the  $j$ -th indicator for country  $i$ .

This made it possible to transform all indicators to a common range of values  $[0; 1]$  and compare countries while avoiding the dominance of individual variables resulting from differences in measurement scales. This normalization method is appropriate because the objective is not to assess the absolute level of individual indicators but rather to determine the relative position of countries within the space of digital-economic characteristics.

At the *second stage*, a set of aggregated indicators (2) was constructed by additive aggregation of the normalized primary indicators of the corresponding subsystems:

$$Xi = \{AGR_i, IND_i, SERV_i, KNOW_i, DIG\_INFRA_i, DIG\_GOV_i, INNOV_i\}, \quad (2)$$

where AGR, IND, SERV, and KNOW represent the aggregated characteristics of the sectoral structure of the economy; DIG\_INFRA denotes digital infrastructure; DIG\_GOV denotes digital governance; and INNOV denotes the innovation and regulatory environment.

At the *third stage*, the composite indicator High Digital Sector Transformation (HDST) was constructed as the sum of the key components that directly characterize the digital maturity of the economy (KNOW, DIG\_INFRA, DIG\_GOV, and INNOV). This approach is based on the concept of the synergistic interaction between knowledge potential, digital infrastructure, public support mechanisms, and innovation activity. Within this indicator, the knowledge sector is used as an outcome characteristic of digital transformation, as it reflects the transition of the economy from the traditional use of technologies to the creation of digital products and competencies.

HDST is a composite measure of the digital maturity of the economy, constructed on the basis of the most relevant components of digital development. The subsequent configurational analysis is not intended to establish causal relationships between individual components and HDST but rather to identify typical combinations of economic and digital characteristics associated with a high level of the composite indicator.

To move from continuous values to assessing countries' membership in specific states of digital development, the *fourth stage* applied the fuzzy calibration method. Unlike the traditional binary classification, calibration was performed using the lower ( $P_{10}$ ) and upper ( $P_{90}$ ) empirical thresholds. Values between these thresholds were determined by linear interpolation.

The membership function for the set of countries with a high level of development was defined as (3):

$$\mu(X_i) = \begin{cases} 0.05, & X_i \leq P_{10} \\ \frac{X_i - P_{10}}{P_{90} - P_{10}}, & P_{10} < X_i < P_{90}, \\ 0.95, & X_i \geq P_{90} \end{cases} \quad (3)$$

where  $\mu(X_i) \in [0.05; 0.95]$  is the degree of membership of country  $i$  in the corresponding set, reflecting the degree to which the respective condition of digital transformation is manifested;  $P_{10}$  is the 10th percentile defining the lower membership threshold, and  $P_{90}$  is the 90th percentile defining a high level of development.

At the *fifth stage*, an original configuration-based comparative analysis of digital transformation was implemented based on the construction of a truth table and the analysis of empirically observed combinations of conditions. Unlike classical Qualitative Comparative Analysis (QCA), the proposed approach does not involve the logical minimization of Boolean configurations but instead employs a procedure of direct comparison of empirically observed combinations of factors. The purpose of this stage is not to establish causal relationships but to identify typical configurations of economic and digital characteristics associated with a high level of the composite indicator HDST. To construct the

configurations, fuzzy membership scores were transformed into binary states using a threshold value of 0.5, interpreted as the boundary of predominant membership in the set of highly developed cases (Equation (4)). Thus, each condition was characterized as either present or absent.

$$X_i^{bin} = \begin{cases} 1, & \mu(X_i) \geq 0.5 \\ 0, & \mu(X_i) < 0.5 \end{cases} \quad (4)$$

where  $\mu(X_i) \geq 0.5$  was interpreted as the presence of the condition, and  $\mu(X_i) < 0.5$  as its absence.

Based on the obtained configurations, a truth table was constructed and used as a tool for systematizing empirically observed configurations of conditions. Each row of the table represents one combination of structural characteristics of the economy and allows its prevalence and association with a high HDST level to be assessed. In the truth table, each configuration of conditions was evaluated according to two criteria: Consistency, defined as the proportion of cases in which the corresponding configuration is associated with a high level of digital transformation, and Coverage, defined as the relative proportion of high digital transformation cases explained by the corresponding configuration. For further interpretation, configurations with Consistency  $\geq 0.8$  were selected, corresponding to a high degree of explanatory power of the causal combination. Unlike classical fsQCA, consistency and coverage in this study are calculated directly from empirical frequencies after binary transformation of the conditions, making it possible to assess the stability and representativeness of individual configurations.

In addition, solution consistency and solution coverage were calculated to evaluate the quality of the obtained solution. Solution consistency and solution coverage were determined based on the set of selected configurations as the proportion of correctly identified cases of high digital transformation among all cases assigned to the solution and among all positive cases, respectively.

At the *sixth stage*, countries were classified using a system of profile indices representing different models of digital development. For each country  $i$  and each profile  $p$ , an additive membership function was constructed as the sum of the corresponding components:  $Score_{ip} = \sum_{k \in \Omega_p} X_{ik}$ , where  $\Omega_p$  is the subset of factors forming profile  $p$ . Accordingly, five profiles were identified:

**1. Digital Service Economy (DSE):**  $Score_i^{DSE} = SERV_i + DIG\_INFRA_i$  – characterized by a high level of development of the service sector (SERV) and digital infrastructure (DIG\_INFRA), enabling the widespread use of digital technologies in service activities.

**2. Innovation Industrial (II):**  $Score_i^{II} = IND_i + INNOV_i$  – characterized by high values of the industrial sector (IND) and the economy's capacity to adopt new technologies (INNOV), reflecting a model of digital industrial modernization.

**3. Government-led Digitalization (GLD):**  $Score_i^{GLD} = DIG\_GOV_i + DIG\_INFRA_i$  – a profile in which digitalization of the public sector (DIG\_GOV) and well-developed digital infrastructure (DIG\_INFRA) play the leading role, indicating an institutionally driven process of digital development.

**4. Emerging Digital Economy (EDE):**  $Score_i^{EDE} = SERV_i + DIG\_GOV_i$  – formed through the combination of digital service development (SERV) and active government support for digitalization (DIG\_GOV), whereby digital services expand through institutional support.

**5. Knowledge-driven Economy (KDE):**  $Score_i^{KDE} = KNOW_i + DIG\_INFRA_i$  – characterized by high values of the knowledge component (KNOW) and digital infrastructure (DIG\_INFRA), reflecting an economy oriented toward innovation, research, and the creation of high value added.

Additionally, a **Mixed Model** category was identified for countries that did not exhibit the dominance of any profile after applying the threshold reduction procedure.

A statistical filtering procedure was subsequently applied to eliminate weakly expressed profiles. For each profile, the 75th percentile,  $Q_{0.75}(Score_p)$ , was calculated, after which threshold reduction was performed (5):

$$Score_{ip}^* = \begin{cases} Score_{ip}, & Score_{ip} \geq Q_{0.75}(Score_p) \\ 0, & Score_{ip} < Q_{0.75}(Score_p) \end{cases} \quad (5)$$

Thus, only the dominant profile characteristics of a country were retained, while weak signals were eliminated.

The final classification was determined according to the principle of maximum dominance (6):

$$Profile_i = \arg \max_p (Score_{ip}^*) \quad (6)$$

If all adjusted scores were equal to zero, the country was classified as belonging to the Mixed Model of digital transformation:  $Profile_i = Mixed Model$ .

It should be noted that some countries may exhibit high values simultaneously for several profile scores. However, in order to ensure an unambiguous classification and improve the interpretability of the results, each country was assigned only the dominant profile corresponding to the maximum adjusted profile score.

To investigate the evolution of digital profiles, the results were spatially visualized using cartographic analysis. In addition, radar charts of country profiles and trajectories of changes in the composite HDST indicator over the period 2019–2024 were constructed.

The proposed methodology was implemented using the Python programming language.

## 4. EMPIRICAL RESULTS

As a result of applying Configuration-based Comparative Analysis and sufficient condition analysis, 91 configurations leading to a positive outcome were identified (Table 1). These combinations of factors most frequently result in the corresponding models of digital development. The overall solution consistency is 0.988, substantially exceeding the accepted threshold of 0.8, indicating that the identified configurations are reliable sufficient conditions. The solution coverage equals 0.923, meaning that the identified pathways explain 92.3% of all successful cases. These findings demonstrate that digital profiles are not shaped by a single factor but emerge from the combined interaction of economic, infrastructural, institutional, and innovation components.

Table 1

Truth table results

| Path | Configuration                                                                             | Positive cases | Reliability |
|------|-------------------------------------------------------------------------------------------|----------------|-------------|
| 1    | AGR_bin=0, IND_bin=1, SERV_bin=0, KNOW_bin=1, DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 13.2%          | 100.0%      |
| 2    | AGR_bin=0, IND_bin=1, SERV_bin=0, KNOW_bin=0, DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 13.2%          | 92.3%       |
| 3    | AGR_bin=0, IND_bin=0, SERV_bin=1, KNOW_bin=1, DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 11.0%          | 100.0%      |
| 4    | AGR_bin=0, IND_bin=0, SERV_bin=1, KNOW_bin=0, DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 6.6%           | 100.0%      |

| Path | Configuration                                                                                | Positive cases | Reliability |
|------|----------------------------------------------------------------------------------------------|----------------|-------------|
| 5    | AGR_bin=0, IND_bin=1, SERV_bin=1, KNOW_bin=1,<br>DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 6.6%           | 100.0%      |
| 6    | AGR_bin=0, IND_bin=0, SERV_bin=0, KNOW_bin=1,<br>DIG_INFRA_bin=0, DIG_GOV_bin=0, INNOV_bin=0 | 4.4%           | 100.0%      |
| 7    | AGR_bin=0, IND_bin=0, SERV_bin=1, KNOW_bin=1,<br>DIG_INFRA_bin=1, DIG_GOV_bin=0, INNOV_bin=1 | 4.4%           | 100.0%      |
| 8    | AGR_bin=0, IND_bin=1, SERV_bin=1, KNOW_bin=0,<br>DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 4.4%           | 100.0%      |
| 9    | AGR_bin=0, IND_bin=0, SERV_bin=0, KNOW_bin=1,<br>DIG_INFRA_bin=0, DIG_GOV_bin=1, INNOV_bin=1 | 3.3%           | 100.0%      |
| 10   | AGR_bin=0, IND_bin=1, SERV_bin=1, KNOW_bin=0,<br>DIG_INFRA_bin=1, DIG_GOV_bin=0, INNOV_bin=1 | 3.3%           | 100.0%      |
| 11   | AGR_bin=0, IND_bin=0, SERV_bin=0, KNOW_bin=1,<br>DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 3.3%           | 100.0%      |
| 12   | AGR_bin=0, IND_bin=0, SERV_bin=1, KNOW_bin=1,<br>DIG_INFRA_bin=0, DIG_GOV_bin=0, INNOV_bin=1 | 2.2%           | 100.0%      |
| 13   | AGR_bin=0, IND_bin=1, SERV_bin=1, KNOW_bin=0,<br>DIG_INFRA_bin=0, DIG_GOV_bin=0, INNOV_bin=1 | 2.2%           | 100.0%      |
| 14   | AGR_bin=0, IND_bin=1, SERV_bin=0, KNOW_bin=1,<br>DIG_INFRA_bin=1, DIG_GOV_bin=0, INNOV_bin=0 | 2.2%           | 100.0%      |
| 15   | AGR_bin=0, IND_bin=1, SERV_bin=0, KNOW_bin=1,<br>DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=0 | 2.2%           | 100.0%      |
| 16   | AGR_bin=0, IND_bin=0, SERV_bin=0, KNOW_bin=0,<br>DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 1.1%           | 100.0%      |
| 17   | AGR_bin=0, IND_bin=0, SERV_bin=1, KNOW_bin=1,<br>DIG_INFRA_bin=0, DIG_GOV_bin=1, INNOV_bin=1 | 1.1%           | 100.0%      |
| 18   | AGR_bin=0, IND_bin=1, SERV_bin=0, KNOW_bin=1,<br>DIG_INFRA_bin=0, DIG_GOV_bin=1, INNOV_bin=1 | 1.1%           | 100.0%      |
| 19   | AGR_bin=0, IND_bin=0, SERV_bin=1, KNOW_bin=1,<br>DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=0 | 1.1%           | 100.0%      |
| 20   | AGR_bin=0, IND_bin=1, SERV_bin=0, KNOW_bin=0,<br>DIG_INFRA_bin=1, DIG_GOV_bin=0, INNOV_bin=1 | 1.1%           | 100.0%      |
| 21   | AGR_bin=1, IND_bin=0, SERV_bin=1, KNOW_bin=0,<br>DIG_INFRA_bin=0, DIG_GOV_bin=1, INNOV_bin=1 | 1.1%           | 100.0%      |
| 22   | AGR_bin=1, IND_bin=0, SERV_bin=1, KNOW_bin=0,<br>DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 1.1%           | 100.0%      |
| 23   | AGR_bin=1, IND_bin=1, SERV_bin=0, KNOW_bin=0,<br>DIG_INFRA_bin=1, DIG_GOV_bin=1, INNOV_bin=1 | 1.1%           | 100.0%      |
| 24   | AGR_bin=1, IND_bin=1, SERV_bin=0, KNOW_bin=1,<br>DIG_INFRA_bin=0, DIG_GOV_bin=1, INNOV_bin=1 | 1.1%           | 100.0%      |

Source: Authors' calculations

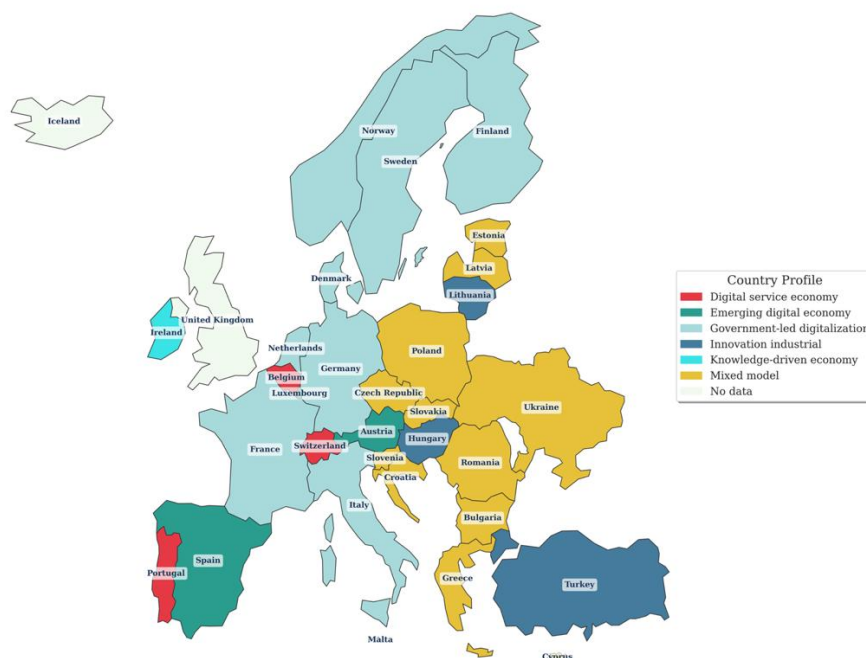
The first five configurations (Table 1) have the greatest explanatory power, as they account for the highest share of positive cases. In particular, the first configuration (13.2% of cases, 100% consistency) combines the absence of a strong agricultural sector with high levels of industrial development, knowledge capacity, digital infrastructure, digital government, and innovation. This suggests that the most common

pathway to a digital economy is the combination of a strong technological base, innovation capacity, and effective digital institutions. The second configuration also covers 13.2% of positive cases with high consistency (92.3%) but differs from the first by a lower level of the knowledge component. This indicates that digital development models can emerge even with a weaker knowledge base, provided that a strong industrial sector, digital infrastructure, government support, and innovation are present.

The third and fourth configurations (11.0% and 6.6% of cases, respectively) illustrate an alternative pathway to digitalization through service sector development. They are characterized by high levels of digital infrastructure, digital government, and innovation combined with a dominant service sector rather than an industrial one. This confirms the importance of digital services as one of the main mechanisms driving the transition to a digital economy. The fifth configuration (6.6% of cases, 100% consistency) is characterized by simultaneously high levels of industrial, service, and knowledge components together with digital infrastructure, digital government, and innovation. This combination reflects the most comprehensive model of digital development, integrating multiple sources of digital value creation.

The remaining configurations account for a smaller share of positive cases (from 1.1% to 4.4%) but generally demonstrate high consistency (100%). They represent more specific patterns of digital transformation, where some components may be less pronounced, while key conditions – digital infrastructure, innovation, or government support – remain decisive.

The configurational analysis results made it possible to classify countries according to the identified profiles. In 2019 (Figure 1), the profile structure of the studied countries was characterized by substantial differences in digital maturity and diverse models of digital economy development. The most common profile was the Mixed Model, indicating that many countries were undergoing a gradual transition without a single dominant development factor. This profile was typical mainly of Central and Eastern European countries, including Bulgaria, Croatia, Czechia, Latvia, Romania, Slovakia, Slovenia, and others.

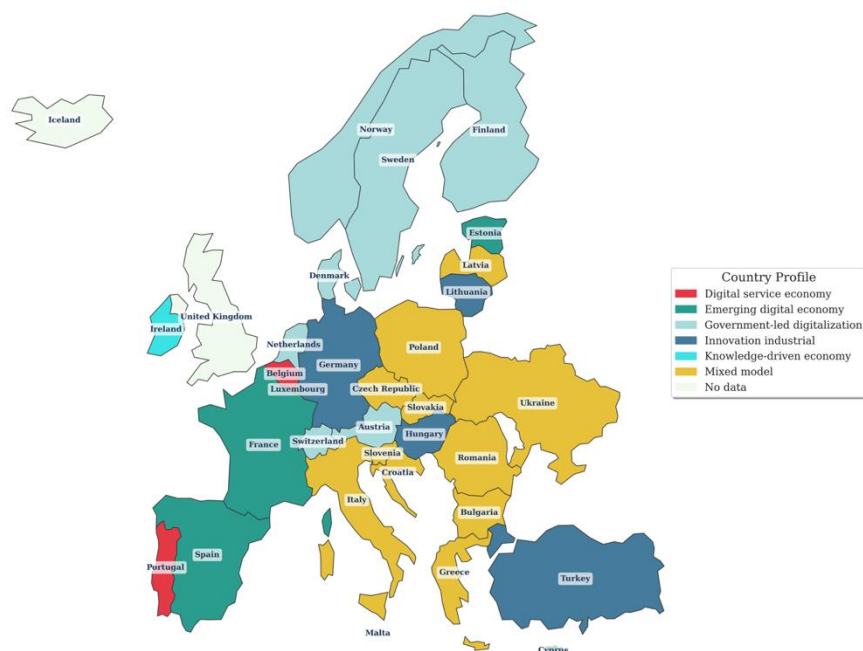


**Figure 1. Country profile mapping, 2019**

*Source:* Authors' calculations

At the same time, the group of advanced European economies exhibited more specialized digital development models. The Nordic countries (Denmark, Finland, Sweden, the Netherlands, Norway, and Germany), together with France and Italy, were characterized by the Government-led Digitalization (GLD) profile, highlighting the major role of public institutions in developing digital infrastructure and digital services in 2019. Ireland displayed a stable Knowledge-driven Economy (KDE) profile, reflecting its focus on knowledge, innovation, and high-technology sectors. Austria, Luxembourg, and Spain belonged to the Emerging Digital Economy (EDE) profile, demonstrating an active transition toward more digitalized economic models. Lithuania, Hungary, and Türkiye exhibited an Innovation Industrial (II) profile, indicating the emergence of their potential for industrial digital modernization during that period.

In 2020 (Figure 2), pandemic-related restrictions strengthened the role of digital technologies in economic activity and public administration. Although many countries remained within the Mixed Model, several shifted toward more distinct digital profiles. In particular, France, Cyprus, and Estonia moved from Government-led Digitalization to Emerging Digital Economy. Cyprus consolidated its position within the EDE profile, while Germany shifted to the Innovation Industrial (II) profile, reflecting the growing role of digital technologies in industry.



**Figure 2. Country profile mapping, 2020**

*Source:* Authors' calculations

The group of countries with high digital maturity remained relatively stable. Denmark, Norway, Finland, the Netherlands, and Sweden stayed within the GLD profile, confirming the stability of their institutional model of digital development. Switzerland and Austria also moved into this profile, suggesting a temporary strengthening of institutional leadership in digital development during the pandemic. Meanwhile, countries with the Digital Service Economy (DSE) profile, such as Belgium and Portugal, emphasized the development of digital services as a key component of their economic structure.

The year 2021 marked the peak of the COVID-19 pandemic and can therefore be regarded as a turning point in digital technology development (Figure 3). Most countries retained their previous profiles, indicating the persistence of institutional and economic digitalization models. The Nordic countries,

together with Switzerland and Austria, continued to dominate the GLD profile, while Ireland remained within KDE, demonstrating the stability of its knowledge-based economy.

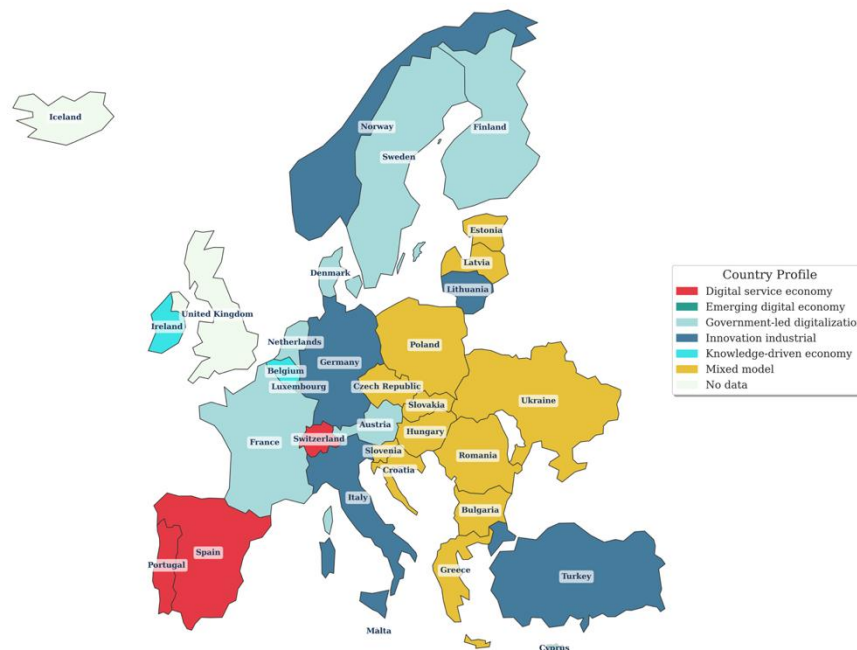


**Figure 3. Country profile mapping, 2021**

*Source:* Authors' calculations

At the same time, structural changes occurred in several countries. Belgium shifted to the KDE profile, indicating a stronger role for the knowledge economy and innovation sectors. Italy followed the sequence Government-led Digitalization → Mixed Model → Innovation Industrial, pointing to intensified industrial digitalization. Germany, Lithuania, and Türkiye retained the Innovation Industrial profile, confirming their orientation toward industrial digital modernization. Hungary and Estonia moved into the Mixed Model, reflecting their gradual digital transformation through a combination of economic, institutional, and technological factors.

In 2022 (Figure 4), the structure of digital profiles was characterized by the gradual transition of several countries toward models centered on digital services and innovation. Countries with the Government-led Digitalization and Knowledge-driven Economy profiles remained the most stable, demonstrating strong institutional capacity and well-developed digital ecosystems.



**Figure 4. Country profile mapping, 2022**

*Source:* Authors' calculations

An important trend was the strengthening of the DSE profile. Portugal and Switzerland returned to the digital service-oriented model that had characterized them in 2019 and 2020. Spain also shifted from EDE to DSE, indicating accelerated digital service development and deeper integration of digital technologies into the business environment. Norway moved from Government-led Digitalization to Innovation Industrial, reflecting the growing importance of the industrial component of digital transformation. At the same time, several countries remained within the Mixed Model, indicating uneven digital convergence across European economies.

In 2023 (Figure 5), clearer patterns of specialization in digital development emerged. The number of countries with the DSE profile increased substantially, reflecting the transition from basic digitalization to an economy in which digital services became an important source of value creation. This group included Belgium, France, Greece, Italy, Portugal, Spain, Switzerland, and Ukraine.



**Figure 5. Country profile mapping, 2023**

*Source:* Authors' calculations

At the same time, changes occurred among countries traditionally characterized by strong government-led digitalization. Sweden shifted from GLD to KDE, demonstrating a stronger focus on innovation, research, and knowledge as the main drivers of development. Poland, Germany, Austria, and Türkiye also changed their digital development trajectories, although these changes may reflect only temporary national circumstances.

By 2024 (Figure 6), a more mature structure of digital profiles had emerged, characterized by a gradual decline in mixed models and stronger specialization. The DSE profile became one of the most common among countries with high digital integration, including Belgium, France, Portugal, Spain, Switzerland, Greece, Austria, and Ukraine. At the same time, the GLD profile remained stable in countries where the state continued to play a leading role in digital development, including Denmark, Finland, Germany, and the Netherlands. The KDE profile remained stable in Ireland and Sweden, confirming the long-term orientation of these economies toward knowledge, innovation, and high-technology industries. The II profile continued to characterize Norway and several other countries where digitalization is closely linked to industrial modernization.



**Figure 6. Country profile mapping, 2024**

*Source:* Authors' calculations

Overall, during 2019–2024, digital profiles evolved gradually from predominantly mixed models toward more specialized models of digital development. Countries with clearly established institutional or innovation advantages proved to be the most stable, whereas those that initially exhibited mixed profiles followed slower and less uniform transition paths. These findings confirm that digital transformation is not merely a technological process but also the result of interaction among public policy, innovation capacity, economic structure, and the level of digital service development.

Analysis of the dominant digital development profiles and their persistence during the study period reveals substantial heterogeneity in the digital transformation trajectories of the 31 countries (Table 2). The Profile persistence indicator, which measures the share of the period during which a country retained its dominant profile, makes it possible to assess the stability of its digital model and the degree of structural consolidation of its development trajectory.

Table 2

Profile persistence results

| Country  | Profiles for 2019-2024            | Dominant profile | Profile persistence | Persistence category |
|----------|-----------------------------------|------------------|---------------------|----------------------|
| Austria  | EDE → GLD → GLD → GLD → EDE → DSE | GLD              | 0.50                | Moderate             |
| Belgium  | DSE → DSE → KDE → KDE → DSE → DSE | DSE              | 0.67                | Moderate             |
| Bulgaria | MM → MM → MM → MM → MM → MM       | MM               | 1.00                | High                 |
| Croatia  | MM → MM → MM → MM → MM → MM       | MM               | 1.00                | High                 |
| Cyprus   | MM → EDE → EDE → EDE → MM → MM    | MM*              | 0.50                | Moderate             |
| Czechia  | MM → MM → MM → MM → MM → MM       | MM               | 1.00                | High                 |
| Denmark  | GLD → GLD → GLD → GLD → GLD → GLD | GDL              | 1.00                | High                 |
| Estonia  | MM → EDE → MM → MM → MM → MM      | MM               | 0.83                | High                 |
| Finland  | GLD → GLD → GLD → GLD → GLD → GLD | GDL              | 1.00                | High                 |
| France   | GLD → EDE → EDE → GLD → DSE → DSE | DSE*             | 0.33                | Low                  |

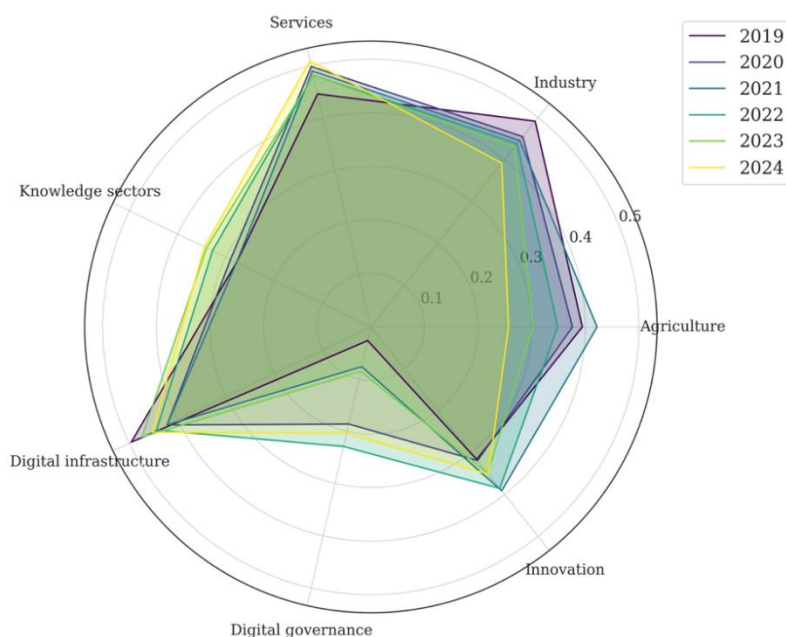
| Country     | Profiles for 2019-2024            | Dominant profile | Profile persistence | Persistence category |
|-------------|-----------------------------------|------------------|---------------------|----------------------|
| Germany     | GLD → II → II → II → GLD → GLD    | GLD*             | 0.50                | Moderate             |
| Greece      | MM → MM → MM → MM → DSE → DSE     | MM               | 0.67                | Moderate             |
| Hungary     | II → II → MM → MM → MM → MM       | MM               | 0.67                | Moderate             |
| Ireland     | KDE → KDE → KDE → KDE → KDE →     | KDE              | 1.00                | High                 |
| Italy       | GLD → MM → II → II → DSE → II     | II               | 0.50                | Moderate             |
| Latvia      | MM → MM → MM → MM → MM → MM       | MM               | 1.00                | High                 |
| Lithuania   | II → II → II → II → II → MM       | II               | 0.83                | High                 |
| Luxembourg  | EDE → EDE → EDE → EDE → EDE → EDE | EDE              | 1.00                | High                 |
| Malta       | KDE → MM → MM → MM → MM → MM      | MM               | 0.83                | High                 |
| Netherlands | GLD → GLD → GLD → GLD → GLD → GLD | GDL              | 1.00                | High                 |
| Norway      | GLD → GLD → GLD → II → II → II    | II*              | 0.50                | Moderate             |
| Poland      | MM → MM → MM → MM → II → MM       | MM               | 0.83                | High                 |
| Portugal    | DSE → DSE → MM → DSE → DSE → DSE  | DSE              | 0.83                | High                 |
| Romania     | MM → MM → MM → MM → MM → MM       | MM               | 1.00                | High                 |
| Slovakia    | MM → MM → MM → MM → MM → MM       | MM               | 1.00                | High                 |
| Slovenia    | MM → MM → MM → MM → MM → MM       | MM               | 1.00                | High                 |
| Spain       | EDE → EDE → EDE → DSE → DSE → DSE | DSE*             | 0.50                | Moderate             |
| Sweden      | GLD → GLD → GLD → GLD → KDE → KDE | GLD              | 0.67                | Moderate             |
| Switzerland | DSE → GLD → GLD → DSE → DSE → DSE | DSE              | 0.67                | Moderate             |
| Türkiye     | II → II → II → II → MM → MM       | II               | 0.67                | Moderate             |
| Ukraine     | MM → MM → MM → MM → DSE → DSE     | MM               | 0.67                | Moderate             |

Notes: \* The dominant profile is selected for 2024, all other things being equal; DSE - Digital service economy; EDE - Emerging digital economy; GLD - Government-led digitalization; II - Innovation industrial; KDE - Knowledge-driven economy; MM - Mixed model.

Source: Authors' calculations

The highest level of stability was observed in countries classified as High persistence, characterized by long-term retention of a single digital profile. This group mainly includes countries whose digital development model is supported by a well-established institutional or structural foundation. In particular, Bulgaria, Croatia, Czechia, Latvia, Romania, Slovakia, and Slovenia remained within the Mixed Model (MM) throughout the study period, with a persistence value of 1.00. This indicates the stability of a mixed digital development model while also suggesting the absence of a rapid transition toward more specialized models, such as the digital service economy or the knowledge-driven economy.

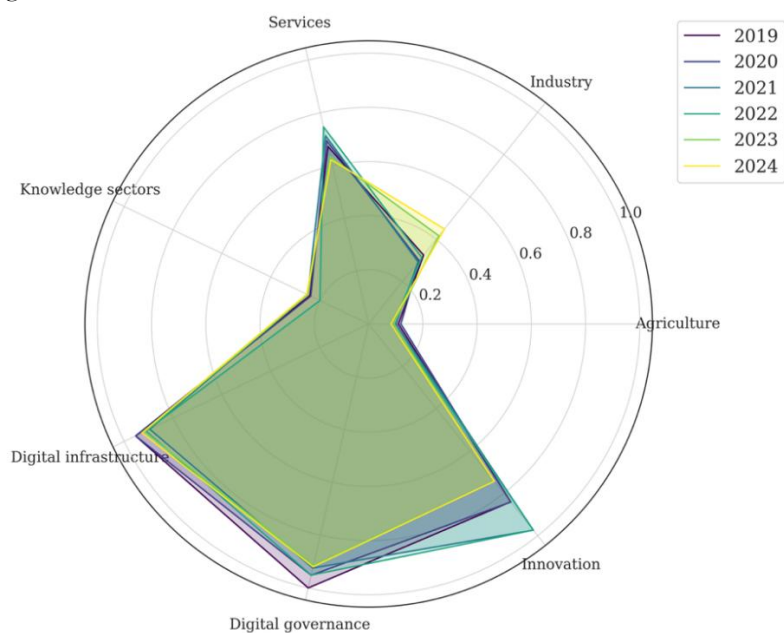
Figure 7 presents the structure of the Mixed Model profile for Romania, which retained the same digital transformation profile throughout the study period (2019–2024). This indicates the absence of any dominant digital development model and the relative stability of the balance between economic and digital components over time. The profile is characterized by moderate values across most structural components without a clear concentration in any particular direction of digital transformation. During the analyzed period, the highest values were observed for the service sector and digital infrastructure, whereas the knowledge sector and digital governance remained less developed. Changes in individual components were minor, confirming the gradual nature of digital transformation without the emergence of clear specialization. Similar structural characteristics were also observed in other countries assigned to the Mixed Model profile (Figures A.1–A.2).



**Figure 7. Dynamics of the Mixed Model structural components (Romania), 2019–2024**

*Source:* Authors' calculations

The group of highly persistent countries also includes Denmark, Finland, and the Netherlands, all characterized by the Government-led Digitalization (GLD) profile with the maximum Profile persistence value of 1.00. This stability reflects the consolidation of a government-led digital development model in which public institutions, digital public services, and systematic digital transformation management play the central role. The structure of this profile for Denmark is shown in Figure 8, while the remaining countries are presented in Figures A.1–A.2.

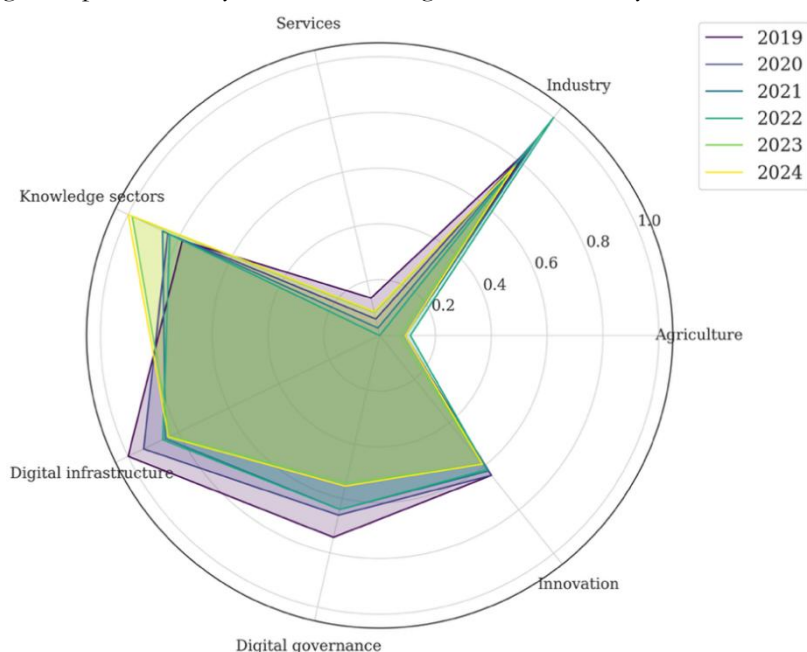


**Figure 8. Dynamics of the Government-led Digitalization structural components (Denmark), 2019–2024**

*Source:* Authors' calculations

Denmark's profile is characterized by high levels of digital infrastructure and digital governance, which represent the key structural components of the country's digital transformation. At the same time, a high level of innovation and a well-developed service sector complement this model, creating a favorable environment for digital technology adoption. The agricultural sector and knowledge sector remain relatively small, reflecting Denmark's economic structure and the characteristics of the Government-led Digitalization profile. Minor fluctuations in individual indicators during the study period did not affect the overall profile configuration, confirming its strong temporal stability and the consistent development of digital transformation.

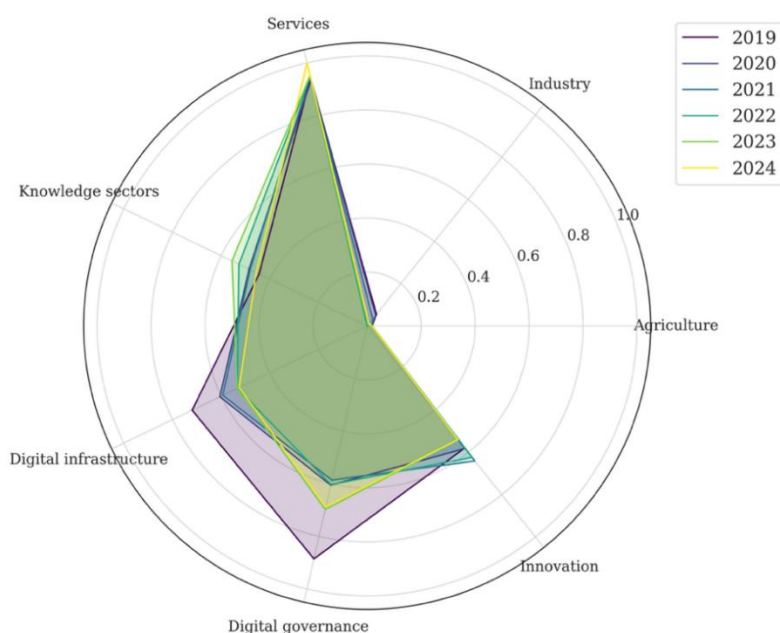
Figure 9 presents the Knowledge-driven Economy (KDE) profile for Ireland, which remained unchanged throughout 2019–2024. The profile is characterized by a strong knowledge sector, advanced digital infrastructure, and a substantial industrial sector, while agriculture and services show relatively lower values. At the same time, digital governance and innovation indicators remain at sufficiently high levels, ensuring a balanced configuration of digital transformation. Despite minor fluctuations in individual components during the analyzed period, the overall profile structure remained virtually unchanged, confirming the high temporal stability of the Knowledge-driven Economy model.



**Figure 9. Dynamics of the Knowledge-driven Economy structural components (Ireland), 2019–2024**

*Source:* Authors' calculations

Luxembourg provides a clear example of the Emerging Digital Economy (EDE) profile, which remained unchanged throughout the analyzed period (Figure 10). The profile is characterized by the stable dominance of the service sector combined with a relatively high level of digital governance, consistent with a digital development model based on institutional support for digitalization and the widespread use of digital services. The balance among key profile components remained relatively stable, although some indicators showed moderate fluctuations. At the same time, the gradual strengthening of the knowledge sector and the maintenance of an adequate innovation level indicate the expansion of the economy's digital potential without changing the dominant development model. Thus, Luxembourg is characterized by an evolutionary digital transformation, in which digital services develop in close interaction with effective digital governance.

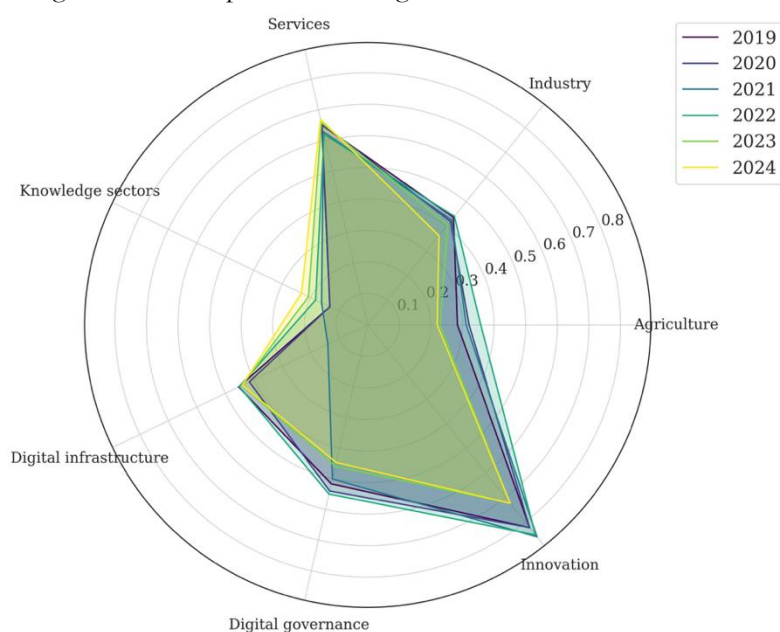


**Figure 10. Dynamics of the Emerging Digital Economy structural components (Luxembourg), 2019–2024**

*Source:* Authors' calculations

A separate group consists of countries with high, but not absolute, profile stability (High persistence with a value of 0.83). This group includes Estonia, Lithuania, Malta, Portugal, and Poland. These countries predominantly retained their dominant profile but occasionally shifted to other profiles, indicating relative stability while undergoing structural adaptation of the digital economy.

For example, Lithuania predominantly remained within the Innovation Industrial (II) profile (Figure 11), while the remaining countries are presented in Figures A.1–A.2.

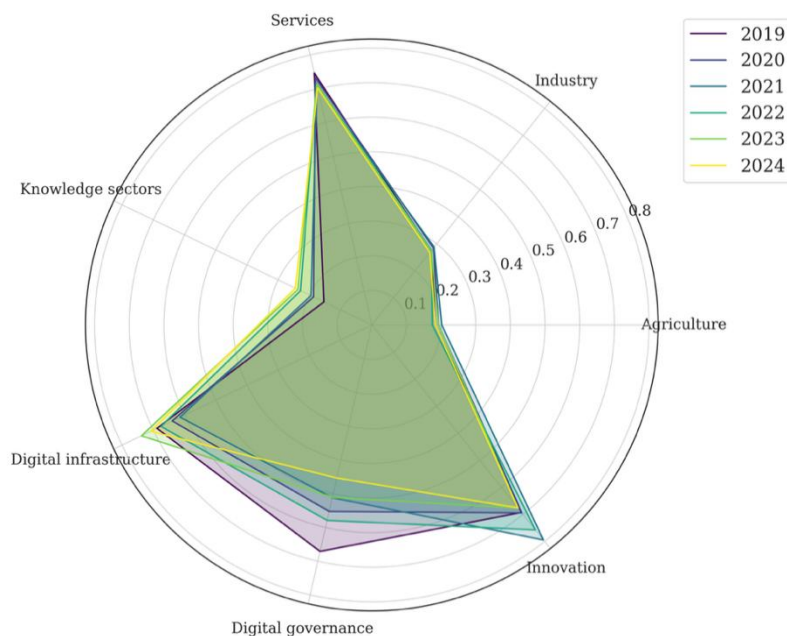


**Figure 11. Dynamics of the Innovation Industrial structural components (Lithuania), 2019–2024**

*Source:* Authors' calculations

This model combines industrial specialization with strong innovation capacity, providing the foundation for digital modernization. Within the profile structure, the innovation component consistently occupies a leading position, while the industrial sector provides the production base for implementing new technologies and digital solutions. The remaining components display moderate values and perform a supporting role without changing the overall profile configuration. Despite fluctuations in some indicators across individual years, the balance among the main structural characteristics remained sufficiently stable, confirming the persistence of a digital transformation model focused on industrial innovation.

Portugal represents the Digital Service Economy (DSE) profile with a High persistence value of 0.83 (Figure 12). Throughout the study period, the service sector remained the dominant profile component, while digital infrastructure maintained a relatively high, although somewhat variable, level. At the same time, the country's innovation capacity remained sufficiently strong to support digital development, whereas the industrial and agricultural sectors played a less significant role. This configuration indicates that Portugal's digital transformation is primarily driven by digital services, while digital infrastructure provides the essential foundation for their operation and further expansion.



**Figure 12. Dynamics of the Digital Service Economy structural components (Portugal), 2019–2024**

*Source:* Authors' calculations

The Moderate persistence category includes the largest number of countries and represents development models characterized by transitions between different digital profiles. This group includes Austria, Belgium, Cyprus, Germany, Greece, Hungary, Italy, Norway, Spain, Sweden, Switzerland, Türkiye, and Ukraine (Figures A.1–A.2).

These countries combine elements of stability with ongoing structural transformation. For example, Austria's dominant profile was Government-led Digitalization (GLD) with a persistence value of 0.50, yet it transitioned between EDE, GLD, and DSE, indicating a gradual restructuring of its digital model. Germany also displayed moderate persistence within the GLD profile (0.50), as its digital development resulted from interaction between government-led digitalization and industrial digital transformation (Innovation Industrial).

Italy and Norway exhibited the Innovation Industrial (II) profile with moderate persistence (0.50), highlighting the importance of industrial modernization in their digital strategies. At the same time, the presence of other profiles in their trajectories suggests an ongoing search for an optimal digital development model balancing government mechanisms, industrial innovation, and digital services.

Countries dominated by the Digital Service Economy (DSE) profile demonstrate different levels of stability. Belgium and Switzerland have a persistence value of 0.67, indicating a relatively stable orientation toward digital services despite occasional transitions to other models, particularly KDE and GLD. Portugal demonstrates high DSE stability (0.83), reflecting the consolidation of a sustainable digital service economy. In contrast, France has the lowest persistence of the dominant profile among the countries studied (0.33), indicating considerable variability in its digital trajectory and successive transitions among government-led, emerging, and service-oriented digitalization models.

Overall, the results indicate that the most stable countries are those with clearly established institutional advantages or a specialized digital development model, namely Government-led Digitalization (GLD), Knowledge-driven Economy (KDE), or Digital Service Economy (DSE). In contrast, countries dominated by the Mixed Model (MM) exhibit high temporal stability but lower structural specialization, suggesting an intermediate stage of digital transformation. Thus, the Profile persistence indicator reflects not only the stability of a digital profile but also different stages in the development of national digital economy models.

The quality of the identified profiles was evaluated using the standard deviation and mean values of their components. Standard deviation analysis (Table 3) makes it possible to assess the internal homogeneity of digital development models and identify the components that contribute most to each profile. Lower standard deviation values indicate greater stability of a given component among countries within a profile group, whereas higher values indicate substantial differences in the development of individual components.

Table 3

Standard deviation of profile components by profile type

| Profile                       | AGR    | IND    | SERV   | KNOW   | DIG_INFRA | DIG_GOV | INNOV  |
|-------------------------------|--------|--------|--------|--------|-----------|---------|--------|
| Digital service economy       | 0.1708 | 0.1020 | 0.0569 | 0.1465 | 0.1008    | 0.1489  | 0.2199 |
| Emerging digital economy      | 0.0857 | 0.1556 | 0.1349 | 0.1254 | 0.1410    | 0.1001  | 0.1379 |
| Government-led digitalization | 0.0455 | 0.0958 | 0.0847 | 0.1151 | 0.1091    | 0.0917  | 0.0775 |
| Innovation industrial         | 0.1748 | 0.0728 | 0.1194 | 0.1076 | 0.1689    | 0.1259  | 0.0941 |
| Knowledge-driven economy      | 0.0250 | 0.3290 | 0.2914 | 0.2210 | 0.1326    | 0.1153  | 0.1453 |
| Mixed model                   | 0.1773 | 0.1542 | 0.1101 | 0.1715 | 0.1052    | 0.2085  | 0.1598 |

Source: Authors' calculations

The Digital Service Economy (DSE) profile is characterized by relatively high stability of the service component ( $SERV = 0.0569$ ), confirming the homogeneity of countries in this group regarding the development of digital services as the key element of their economic structure. The industrial component ( $IND = 0.1020$ ) and digital infrastructure ( $DIG\_INFRA = 0.1008$ ) also exhibit low variability. In contrast, the greatest variation is observed in innovation ( $INNOV = 0.2199$ ), indicating differences in

countries' ability to convert digital services into innovation-driven economic advantages. Thus, the DSE profile shares a common orientation toward digital services but differs in innovation capacity.

The Emerging Digital Economy (EDE) profile demonstrates the greatest stability in the agricultural component ( $AGR = 0.0857$ ) and digital governance ( $DIG\_GOV = 0.1001$ ). This indicates considerable similarity among countries actively building their digital economies in terms of basic institutional conditions. The highest variability within this profile is observed in the industrial sector ( $IND = 0.1556$ ) and digital infrastructure ( $DIG\_INFRA = 0.1410$ ), reflecting differences in technological readiness and the scale of digital modernization.

The Government-led Digitalization (GLD) profile is characterized by the lowest standard deviation across most components, indicating high internal homogeneity. The agricultural sector is the most stable component ( $AGR = 0.0455$ ), while the remaining components also exhibit relatively low variability. The highest values are observed for the knowledge component ( $KNOW = 0.1151$ ) and digital infrastructure ( $DIG\_INFRA = 0.1091$ ), although these remain comparatively low. This confirms that countries with the GLD profile share the most consistent digital development model, centered on effective public management of digital transformation.

The Innovation Industrial (II) profile is characterized by substantial variability in digital infrastructure ( $DIG\_INFRA = 0.1689$ ) and the agricultural component ( $AGR = 0.1748$ ), indicating differences in technological capacity and economic structure across countries. At the same time, the industrial component has a low standard deviation ( $IND = 0.0728$ ), which is expected since industry is the defining feature of this profile. These results confirm that countries in this group share a common focus on industrial digitalization while differing in infrastructure and supporting development factors.

The Knowledge-driven Economy (KDE) profile exhibits the greatest heterogeneity among all models analyzed. The highest standard deviation values are observed for the industrial ( $IND = 0.3290$ ), service ( $SERV = 0.2914$ ), and knowledge ( $KNOW = 0.2210$ ) components. This indicates substantial differences in economic structure, knowledge-sector development, and the scale of innovation resource utilization. In contrast, the agricultural component shows very low variability ( $AGR = 0.0250$ ), highlighting its secondary role in this profile. Thus, KDE represents the most specialized but also the most heterogeneous digital development model.

The Mixed Model (MM) profile is characterized by the greatest balance across components while simultaneously exhibiting considerable variability in several indicators. The highest standard deviation values are observed for digital governance ( $DIG\_GOV = 0.2085$ ) and the agricultural component ( $AGR = 0.1773$ ), indicating differences in institutional readiness and economic structure among countries in this group. Digital infrastructure ( $DIG\_INFRA = 0.1052$ ) and the service sector ( $SERV = 0.1101$ ) display relatively low variability. This confirms that the Mixed Model brings together countries with a similar overall level of digital integration but different internal mechanisms supporting it.

Overall, the results indicate that digital development profiles differ not only in their dominant characteristics but also in their degree of internal homogeneity. Government-led Digitalization is the most stable model, with the smallest variation across digital development components. In contrast, the Knowledge-driven Economy exhibits the greatest structural heterogeneity, reflecting differences in the scale of knowledge and innovation ecosystems. Digital Service Economy and Innovation Industrial display clearer specialization, whereas Emerging Digital Economy and the Mixed Model represent transitional stages of digital transformation with greater variation across individual components.

Analysis of the mean values of digital development components (Table 4) makes it possible to identify the key characteristics of each profile and determine the factors shaping the corresponding digital transformation models.

Table 4

Mean values of profile components by profile type

| Profile                       | AGR    | IND    | SERV   | KNOW   | DIG_INFRA | DIG_GOV | INNOV  |
|-------------------------------|--------|--------|--------|--------|-----------|---------|--------|
| Digital service economy       | 0.1965 | 0.3069 | 0.7321 | 0.2716 | 0.7387    | 0.5318  | 0.6390 |
| Emerging digital economy      | 0.1128 | 0.1629 | 0.7984 | 0.3915 | 0.5629    | 0.7057  | 0.5881 |
| Government-led digitalization | 0.1348 | 0.3619 | 0.6054 | 0.3315 | 0.8010    | 0.8758  | 0.8400 |
| Innovation industrial         | 0.2879 | 0.4745 | 0.5367 | 0.1768 | 0.5598    | 0.4996  | 0.7830 |
| Knowledge-driven economy      | 0.0884 | 0.5928 | 0.3156 | 0.7039 | 0.7829    | 0.6017  | 0.6368 |
| Mixed model                   | 0.2758 | 0.3621 | 0.5694 | 0.2738 | 0.4594    | 0.4126  | 0.5098 |

Source: Authors' calculations

The Digital Service Economy (DSE) profile is characterised by high values of the service component ( $SERV = 0.7321$ ) and digital infrastructure ( $DIG\_INFRA = 0.7387$ ), indicating a strong orientation toward digital services and technological readiness. At the same time, lower values for the industrial ( $IND = 0.3069$ ) and agricultural ( $AGR = 0.1965$ ) components confirm the predominance of a service-based economy.

The Emerging Digital Economy (EDE) profile is defined by a highly developed service sector ( $SERV = 0.7984$ ) and strong digital governance ( $DIG\_GOV = 0.7057$ ). This combination reflects the transitional nature of the model, where digital services expand with institutional support.

The Government-led Digitalization (GLD) profile records the highest values for digital governance ( $DIG\_GOV = 0.8758$ ), digital infrastructure ( $DIG\_INFRA = 0.8010$ ), and innovation ( $INNOV = 0.8400$ ). This characterizes a model in which public policy and effective digital institutions are the main drivers of digital transformation.

The Innovation Industrial (II) profile exhibits the highest level of industrial development ( $IND = 0.4745$ ) together with strong innovation ( $INNOV = 0.7830$ ). This indicates a focus on industrial digital modernization, technological upgrading, and innovation adoption in manufacturing.

The Knowledge-driven Economy (KDE) profile is characterized by the highest value of the knowledge component ( $KNOW = 0.7039$ ) and a high level of digital infrastructure ( $DIG\_INFRA = 0.7829$ ). This model is based on human capital development, research, innovation, and high-technology sectors.

The Mixed Model (MM) profile has the most balanced indicator structure, without a clearly dominant component. The highest values are observed for the service component ( $SERV = 0.5694$ ) and innovation ( $INNOV = 0.5098$ ), characterizing it as an intermediate model of digital development.

Analysis of the High Digital Sector Transformation Index during 2019–2024 (Figure 13) demonstrates substantial differences among countries in terms of digital structural characteristics and confirms significant variation in digital development trajectories. The index ranges from the lowest values in countries with less developed digital ecosystems to high values in countries with advanced digital infrastructure, strong innovation capacity, and effective digital governance mechanisms.

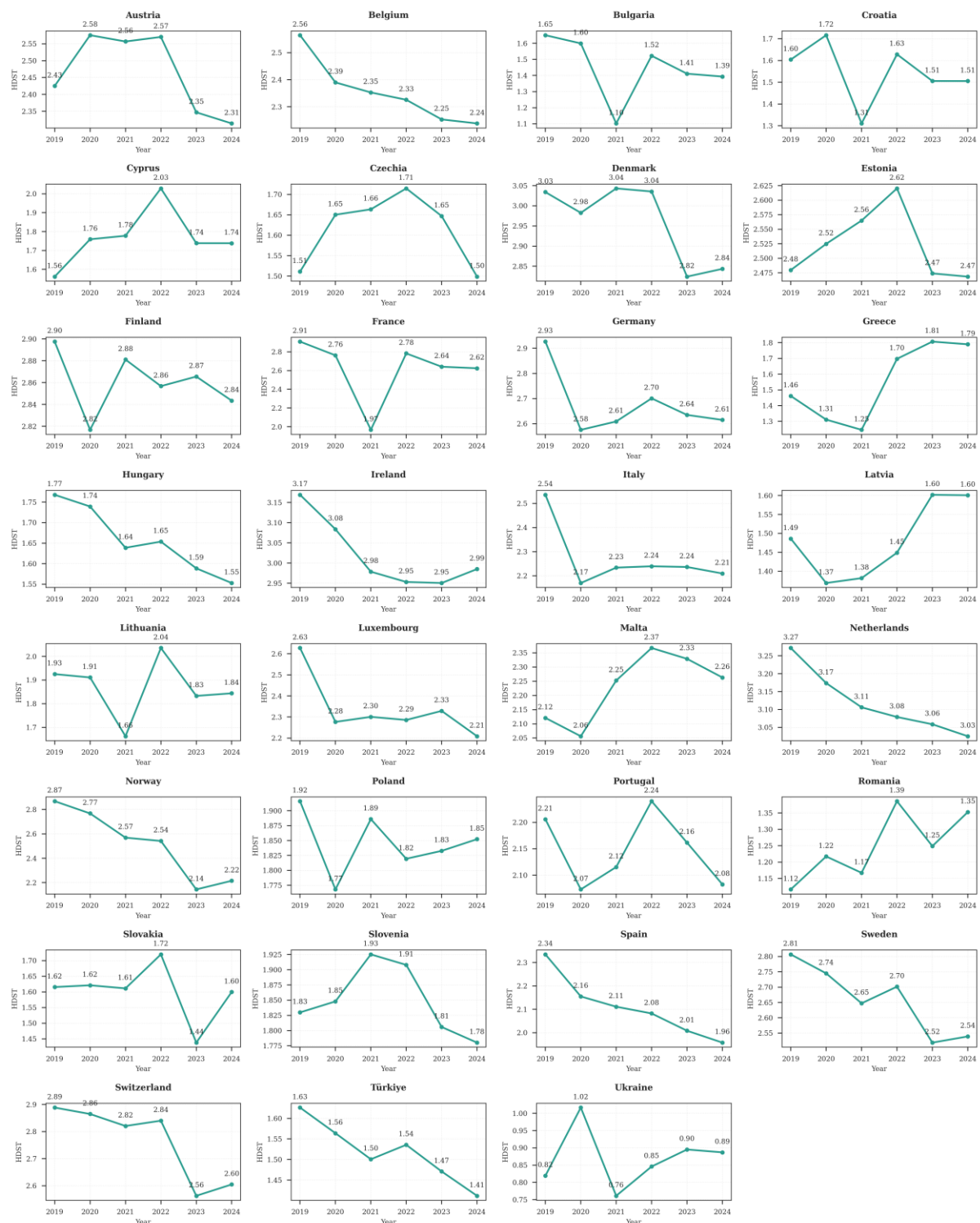


Figure 13. High Digital Sector Transformation Index trajectory, 2019–2024

Source: Authors' calculations

The highest High Digital Sector Transformation Index values throughout the study period were consistently recorded by the Netherlands, Ireland, Denmark, Finland, Germany, France, Switzerland, Sweden, and Estonia. In 2024, the leading positions were retained by the Netherlands (3.0253), Ireland

(2.9852), Denmark (2.8435), and Finland (2.8435). This indicates the sustained development of highly advanced digital models characterized by strong technological capacity, advanced digital infrastructure, and a high level of digital technology integration into the economy and society.

The group with medium High Digital Sector Transformation Index values consisted mainly of Western and Southern European countries, including Austria, Belgium, Italy, Luxembourg, Malta, Norway, Portugal, and Spain. This group was characterized by relatively stable index values with only minor fluctuations during the study period. At the same time, several countries showed a gradual decline in the index, which may indicate changes in the structure of digital development or convergence toward more homogeneous digital transformation models.

The lowest index values were observed in Central and Eastern European countries, including Romania, Bulgaria, Cyprus, Greece, Croatia, Czechia, Latvia, Lithuania, Poland, Slovakia, Slovenia, Türkiye, Hungary, and Ukraine. Particularly low values were recorded for Ukraine, where the index remained below 1.0 for most of the study period (0.8193 in 2019 and 0.8870 in 2024). This indicates a persistent gap in digital maturity compared with the leading countries.

The time series does not reveal a uniform trend of either growth or decline in the High Digital Sector Transformation Index across all countries. Most countries exhibited fluctuations while gradually converging toward stable levels. The most noticeable declines were observed in France, Norway, Switzerland, and several other countries with initially high values, whereas some countries with lower initial positions demonstrated partial improvement.

These findings indicate persistent digital disparities among European countries throughout 2019–2024. At the same time, the gap between country groups has gradually evolved: countries with high digital maturity have maintained stable performance, while countries with lower values have continued to build the foundations for digital development. Thus, the High Digital Sector Transformation Index confirms the existence of different levels of digital transformation and reflects the structural heterogeneity of national digital development models.

Overall, the configurational analysis confirms that digital profile formation is a multifactor process. The most common characteristics of configurations associated with a high level of digital transformation are advanced digital infrastructure, strong innovation capacity, digital government, and specific combinations of sectoral characteristics depending on the digital development model.

## 5. DISCUSSION

The empirical findings of this study demonstrate that advanced digital development does not follow a single, symmetrical trajectory; rather, European countries with comparable levels of digital maturity achieve their status through highly diverse structural configurations. This evidence directly challenges traditional linear econometric estimations of digital growth, which assume simple, proportional relationships between digital inputs and macroeconomic output. Instead, this study's identification of multiple equifinal configurations associated with high levels of Digital Sector Transformation (Table 1) validates the non-linear, set-theoretic conceptualization of digital maturity proposed by Mattke et al. (2022) and Hu (2026). Specifically, while certain nations achieve digital growth through service-oriented pathways (such as Paths 3 and 4), others succeed through industrial-innovation trajectories (such as Paths 1 and 2). This supports the argument of Tan & Shu (2026) that optimal digital transformation is achieved through configuration-specific alignments of technological, organizational, and environmental factors.

The absolute temporal stability (persistence value of 1.00) of the Government-led Digitalization profile observed in Denmark, Finland, and the Netherlands (Table 2) underscores the critical role of institutional frameworks and public administration in cultivating stable, long-term digital ecosystems. This aligns closely

with scholarly assertions that national governments serve as the primary platforms for algorithmic governance and administrative reform (Androniceanu & Streimikiene, 2026; Dinu et al., 2026). It also confirms that digital maturity within public institutions represents a key determinant of systemic resilience and administrative efficiency (Bartuseviciene & Butkus, 2024; Sira & Kuzior, 2025). Similarly, the long-term persistence of the Knowledge-driven Economy profile in Ireland reinforces the argument that knowledge generation, advanced digital infrastructure, and specialized human capital are essential structural drivers that enable quaternary sectors to restructure global value creation (Meidute-Kavaliauskiene et al., 2026).

In contrast to these specialized, highly persistent models, the prevalence and absolute stability (1.00) of the Mixed Model in Central and Eastern European states (specifically Bulgaria, Croatia, Romania, and Slovakia) – indicate a slower, path-dependent transition. These structural patterns reflect the deep-seated regional digital divides and intra-regional disparities that persist across European Union member states (Brodny & Tutak, 2023; Valaskova et al., 2025). The absence of a dominant developmental driver in these countries suggests they occupy an intermediate phase, facing challenges in translating digital assets into specialized economic advantages. Furthermore, under acute geopolitical or macroeconomic shocks – as evidenced by Ukraine’s persistently low HDST outcomes – a deficit in specialized digital maturity can compromise economic security, highlighting the need for targeted institutional trust and governance frameworks to stabilize national systems and rebuild infrastructure (Topazly et al., 2026; Tsymbal & Demediuk, 2025).

Finally, the gradual transition of several Western European economies toward the Digital Service Economy profile by 2024 (Figure 6) reflects a structural shift toward service-oriented digital value creation. This trajectory is closely linked to the modern regulatory and ecological demands facing European markets, particularly within the “twin transition” framework where digital capabilities serve as foundational blocks for green innovation and carbon mitigation (Alodat & Dong, 2026; Dinu et al., 2025; Nguyen et al., 2026). Notably, standard deviation analysis reveals that the DSE profile exhibits the highest variation in innovation capacity ( $INNOV = 0.2199$ ) (Table 3), suggesting that while these countries share a common orientation toward digital services, their ability to convert these services into competitive innovation-driven advantages remains uneven. This developmental gap highlights the critical role of adaptive skills, suggesting that transition economies must actively mitigate the “reskilling paradox” and overcome workforce inertia to achieve successful public and private sector digital transformation (Tagaev & Bilan, 2026b; Zhilkishbayeva et al., 2025).

## 6. CONCLUSION

This study proposes a comprehensive approach to analyzing digital transformation by combining economic and digital indicator aggregation, fuzzy calibration, configurational analysis, and country profiling. Unlike approaches based solely on composite indices, the proposed methodology accounts for the structural heterogeneity of digital transformation and identifies characteristic combinations of economic and digital features associated with different levels of digital maturity.

The findings confirm that a high level of digital transformation does not correspond to a single universal development model. Countries with similar values of the High Digital Sector Transformation (HDST) indicator may differ substantially in economic structure, digital infrastructure, digital governance, and innovation capacity. The configurational analysis identified typical combinations of these characteristics associated with a high level of digital transformation and confirmed the existence of several alternative digital development models.

Country profiling identified five dominant digital transformation models – Digital Service Economy, Innovation Industrial, Government-led Digitalization, Emerging Digital Economy, and Knowledge-driven

Economy – as well as the Mixed Model category, which includes countries without a clearly dominant profile. The results demonstrate that countries with comparable levels of digital maturity may achieve them through different combinations of structural, institutional, and technological characteristics.

The practical value of the proposed approach lies in its potential to support differentiated public policies for digital transformation. Unlike universal digitalization strategies, the profiling approach considers the specific characteristics of national economic structures, digital infrastructure, institutional environment, and innovation capacity, enabling more evidence-based prioritization of digital development policies.

The scientific contribution of this study is the development of an original approach to configurational analysis and digital transformation profiling that comprehensively captures the relationships between countries' economic and digital characteristics. The proposed methodology can serve as an analytical tool for comparative international studies of the digital economy, assessment of structural features of digital transformation, and long-term monitoring of changes in digital development models.

*Study limitations.* The proposed approach is designed to identify typical configurations of economic and digital characteristics and to develop digital transformation profiles for countries. The identified configurations should be interpreted as empirical models describing the structural features of digital development rather than evidence of causal relationships between individual components. Furthermore, the results depend on the selected indicators, the aggregation procedure, and the empirical calibration thresholds determined by the characteristics of the analyzed sample. Therefore, the proposed approach should be regarded as a tool for comparative analysis and digital transformation profiling that can be extended by incorporating additional economic, institutional, technological, or regional characteristics, as well as validated using broader international samples and longer time horizons.

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## DATA AVAILABILITY STATEMENT

The research data is available at the link: Yarovenko, H. & Bozhenko, V. (2026). Economic and Digital Indicators for European Countries (2019–2024) [Dataset]. Zenodo. <https://doi.org/10.5281/zenodo.21399220>

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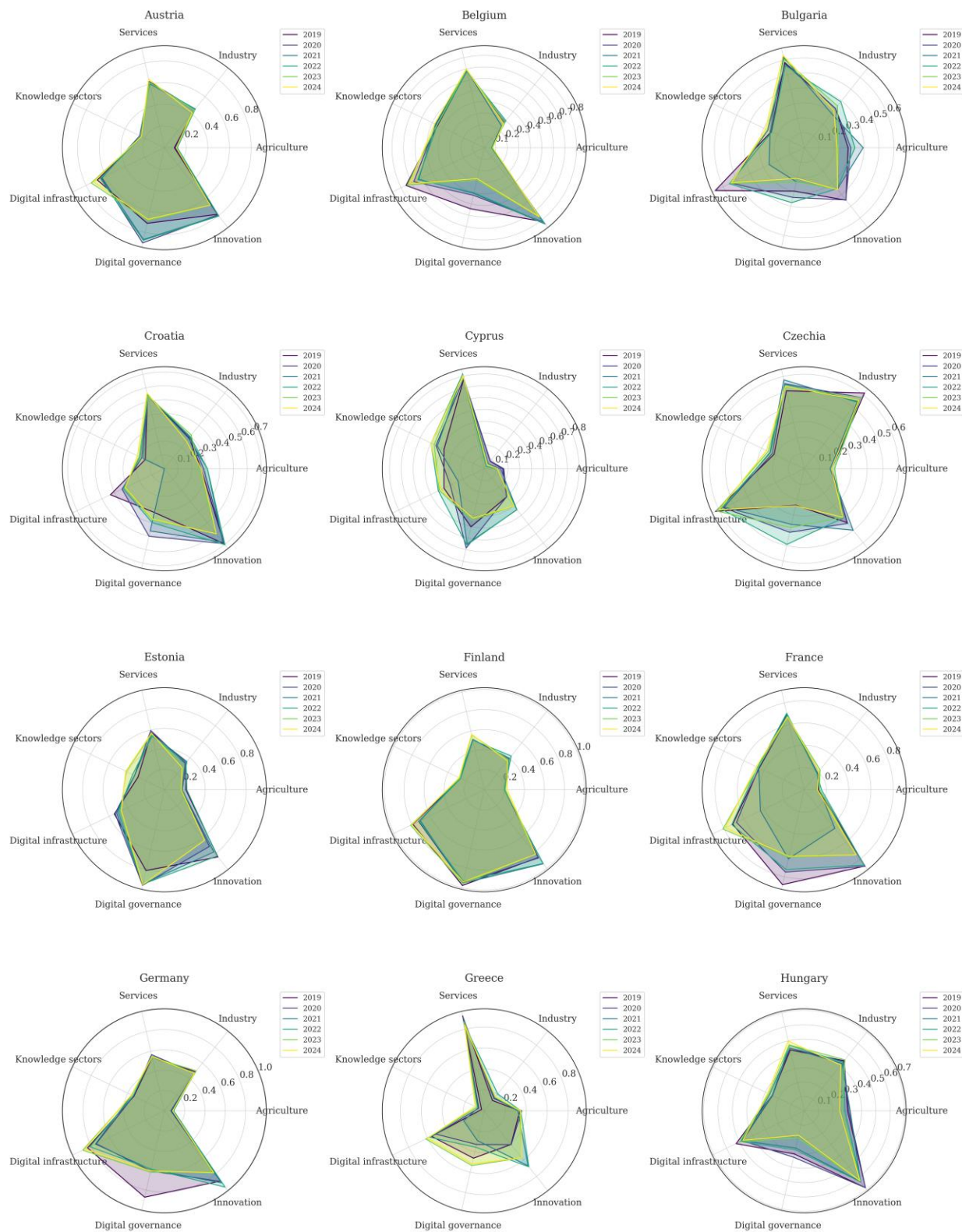
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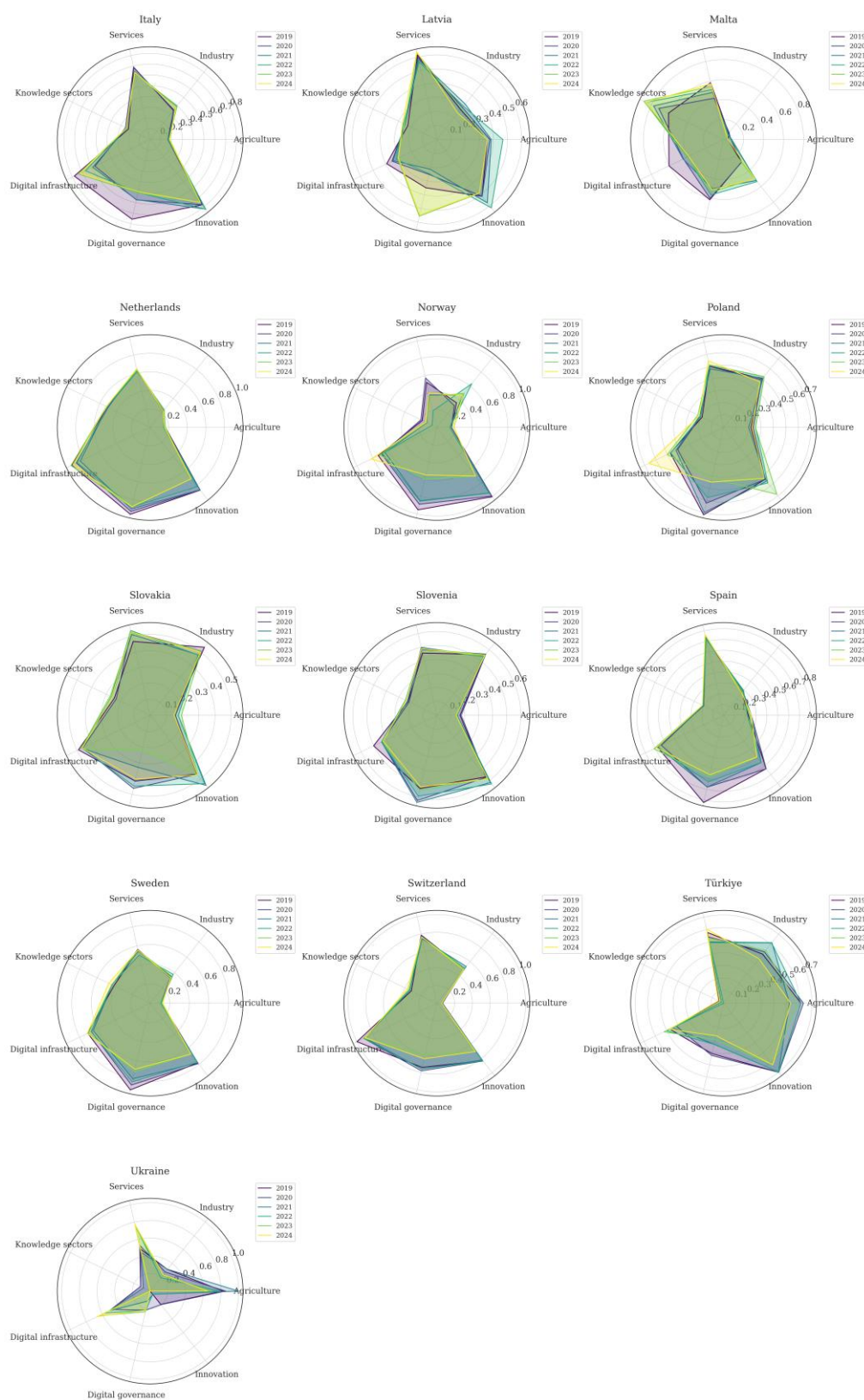
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## APPENDIX A



**Figure A.1. Dynamics of structural components for different countries, 2019–2024**

*Source:* Authors' calculations



**Figure A.2. Dynamics of structural components for different countries, 2019–2024**

*Source:* Authors' calculations