

Roman Zvorych

*Doctor of Economic Sciences, Professor,
Head of the Department of International Economic Relations
West Ukrainian National University*

Dmytro Harapko

*PhD student at the Department of International Economic Relations
West Ukrainian National University*

DOI: <https://doi.org/10.30525/978-9934-26-634-8-11>

MODERATING GOVERNANCE AND CULTURE IN THE DIGITAL–SUSTAINABILITY NEXUS: TOWARDS A SOCIETY 5.0 FRAMEWORK FOR THE EUROPEAN UNION

Summary

The study addresses a critical gap in understanding how digital readiness translates into sustainable development within the diverse institutional and cultural landscape of the European Union. Despite growing alignment between the UN 2030 Agenda and Japan’s Society 5.0 vision, empirical evidence on how governance and cultural factors condition their convergence remains limited. Using data from the Network Readiness Index (2024), Sustainable Development Goals Index (2024), Worldwide Governance Indicators (2023), and Hofstede’s Individualism scores, the research applies a moderated cluster analysis across 27 EU member states. The results reveal four regional typologies – Nordic Leaders, Western Integrators, Southern Adaptors, and Eastern Emergers – that reflect structural asymmetries in digital maturity, governance quality, and social orientation. Regression outcomes show that while digital readiness positively correlates with SDG progress, governance effectiveness amplifies this relationship, whereas cultural individualism slightly attenuates it. These findings validate the hypothesis that sustainable digitalisation requires the alignment of technological, institutional, and cultural systems. The paper concludes that the path toward Europe’s Society 5.0 must integrate digital innovation with good governance and social welfare priorities to achieve inclusive, resilient sustainability.

Introduction

The rapid advancement of digital technologies and their integration into socio-economic systems have rendered digital transformation a cornerstone of contemporary industrial policy and sustainable development strategies worldwide. Over the last decade, digitalisation has transcended its purely technological origins to become a structural force reshaping governance,

production, and welfare paradigms. By merging physical and cyber spaces, digital transformation enables new forms of value creation, social participation, and environmental monitoring, key ingredients of the transition toward knowledge-based, resilient, and sustainable societies.

In this context, Japan's *Society 5.0* paradigm, introduced in the *5th Science and Technology Basic Plan (2016)*, embodies a human-centred vision that seeks to harness cyber-physical convergence to address pressing societal challenges—such as ageing populations, labour shortages, and ecological degradation—while simultaneously fostering inclusive prosperity [1]. Unlike the efficiency-oriented *Industry 4.0* model, *Society 5.0* positions technological innovation within a normative framework of human well-being and social cohesion. Its goal is to ensure that economic modernisation serves not only productivity but also the broader principles of equity, trust, and sustainability.

Simultaneously, the United Nations' *2030 Agenda for Sustainable Development*, with its 17 Sustainable Development Goals (SDGs), provides a comprehensive global framework for balancing economic growth, social equity, and environmental stewardship. The synergy between these paradigms—technological humanism in *Society 5.0* and planetary sustainability in the *2030 Agenda*—has created new opportunities for policy innovation. Together, they offer a roadmap for turning digitalisation from a disruptive technological trend into a strategic tool for sustainable and inclusive development.

Within the European Union (EU), this convergence has taken the form of the *Digital Decade Policy Programme 2030*, which sets out measurable digital targets across infrastructure, skills, business transformation, and public services. Yet, despite this ambitious vision, the European digital–sustainability nexus remains asymmetrical. While Northern and Western Europe exhibit advanced digital maturity, strong institutions, and coherent sustainability performance, Southern and Eastern regions lag, constrained by governance deficits, infrastructural gaps, and socio-cultural divergences [3–6]. Understanding the structural roots of these disparities has become a research priority, as digitalisation is increasingly viewed as both an enabler and a mirror of broader socio-institutional capacity.

Despite substantial progress in mapping the relationship between digital readiness and SDG attainment [3–7], several critical gaps persist. First, much of the empirical literature relies on aggregate indices that capture correlations but overlook *contextual moderators*—particularly governance quality and cultural orientation—that may condition the translation of digital readiness into sustainability outcomes [3]. Second, while cluster analyses have successfully identified regional disparities in digital maturity and SDG performance [4; 5; 7], they typically employ *unmoderated* approaches, limiting their explanatory power for understanding how institutional and cultural asymmetries amplify or

attenuate digital–sustainability linkages. Third, and perhaps most crucially, the applicability of *Society 5.0* principles to the EU context—especially in bridging the gap between Nordic digital leaders and Eastern emergers—has yet to be empirically validated through moderated or regionally sensitive analytical frameworks [1; 5].

These gaps carry both theoretical and practical implications. From a theoretical perspective, existing models often conceptualise digitalisation as a linear driver of sustainability, overlooking potential nonlinearities, threshold effects, and socio-cultural contingencies that shape developmental outcomes [7; 8; 9]. From a policy perspective, the absence of an integrated analytical lens hampers the design of targeted, regionally tailored interventions—precisely those required to ensure that the EU’s digital transformation also fulfils its sustainability and cohesion mandates.

The unresolved aspect of the issue is therefore the lack of a regionally nuanced, *moderated analytical model* that combines four core dimensions: digital readiness (measured by the *Network Readiness Index*), governance quality (captured by the *Worldwide Governance Indicators*), cultural individualism (according to *Hofstede*), and sustainability outcomes (via the *SDG Index*). Such integration is essential for capturing the interplay between technological capacity, institutional performance, and societal values.

This article aims to fill this gap by developing and applying a moderated cluster analysis framework to examine how governance effectiveness and cultural individualism condition the impact of digital readiness on SDG progress across EU member states. By situating the analysis within the *Society 5.0* conceptual paradigm and the EU’s digital policy landscape, the study seeks to generate actionable insights for designing context-sensitive innovation strategies that advance inclusive, human-centred, and sustainable digital transformation. Ultimately, the research contributes to the growing body of evidence that sustainable development in the digital era depends not solely on technological sophistication but on the alignment of digital systems with governance integrity and cultural values.

Chapter 1. Governance and cultural moderation in the digital–sustainability nexus

The literature on the intersection of digital transformation, Society 5.0, and the Sustainable Development Goals (SDGs) has proliferated in recent years, reflecting the growing recognition that technological advancement must be harnessed to address multifaceted societal challenges while advancing sustainability [2; 3]. This review synthesises key contributions from the provided sources, including foundational works on Society 5.0 [1; 2; 4; 5], empirical cluster analyses of EU digital readiness and SDG progress, systematic reviews of digital technology’s role in sustainability [6; 7], and

emerging studies on social welfare preferences and nonlinear tipping points in European sustainability [7; 8; 9; 10]. It traces the evolution of the discourse, identifies theoretical and empirical gaps, and underscores the need for moderated, regionally nuanced frameworks to bridge these paradigms.

Society 5.0, introduced in Japan's 2016 5th Science and Technology Basic Plan, shifts from Industry 4.0's efficiency focus to a human-centric 'super-smart society' [1; 2]. It combines cyberspace and physical space to address issues like aging, resource shortages, and economic gaps. Fukuyama traces its evolution from Society 1.0 to 4.0, highlighting the integration of cyber-physical systems and stakeholder involvement to create value. This aligns with global digital efforts with IoT, AI, and big data driving policies such as Germany's Industry 4.0, the US Industrial Internet, and China's Made in China 2025.

The UN's 2030 Agenda [3] offers a complementary framework, with SDGs serving as a comprehensive system for economic growth, social solutions, and planetary prosperity, guided by the principle of 'leaving no one behind'. This emphasis on inclusivity aligns with Society 5.0's human-centric ethos, positioning digital tools as enablers for tackling global challenges like resource depletion and inequality [1; 3; 4; 5].

Empirical studies have increasingly mapped the impact of digital transformation on the SDGs, revealing both synergies and disparities. Košíková and Vašaničová [4] employ a two-level cluster analysis using the 2024 Network Readiness Index (NRI) and selected SDGs (3, 4, 5, 7, 11, 15) across EU countries. Their findings highlight significant variances: digitally advanced nations (e.g., the Nordics) underperform on sustainability metrics, while lower-digital nations (e.g., Eastern Europe) excel in social SDGs such as health (SDG 3) and education (SDG 4). A moderate positive correlation ($r_s = 0.526$) between NRI and SDG clusters underscores regional patterns and calls for integrated digital-sustainability policies.

Complementing this, Fonseca et al. [5] utilise the Global Digitalisation Index (GDI) in a partial correlation and cluster analysis of EU states, identifying 12 initial GDI-SDG links (positive for SDG 3, 5, 9, 11, 16; negative for SDG 15). After controlling for governance and culture, these reduce to three robust associations: GDI enhances health (SDG 3) and innovation (SDG 9), but undermines life on land (SDG 15). Regression reveals digital transformation's effectiveness is culturally contingent, yielding four country profiles and supporting targeted Industry 5.0 policies.

Saha et al. [6] offer a systematic PRISMA review of 141 articles, confirming digital technology's catalytic role in SDGs (e.g., AI in agriculture for SDG 2, machine learning for supply chains [10]). However, they warn against adverse effects such as carbon intensification [11], advocating for collaborative governance and capacity building to facilitate integration.

Recent scholarship introduces social and nonlinear dimensions to the digital-SDG nexus. Liashenko and Dluhopolskyi [7] explore how social welfare preferences (SWP) influence Society 5.0 achievement, arguing that economic success alone does not guarantee societal advancement; diverse SWP—ranging from egalitarian to meritocratic—shape trajectories towards human-centred progress. Using both theoretical and empirical methods, they demonstrate SWP’s impact on well-being, urging policies that align technologies with societal values for inclusive sustainability. This aligns with welfare typologies [12], where governance quality mediates ecological outcomes.

Liashenko et al. [8] advance this by employing a nonlinear Multivariate Adaptive Regression Splines (MARS) approach to European tipping points within the ‘People, Planet, Prosperity’ framework. Using data from 2000–2024 and PCA-derived indices, they identify thresholds: social progress (People) accelerates beyond 0.839, environmental stability (Planet) limits extremes, and prosperity enhances synergies only when socially grounded. With an adjusted R^2 of 0.963, the model captures interactions (e.g., People compensating for Planet deficits), emphasising synergies over trade-offs [12; 13]. This nonlinear perspective critiques linear SDG assessments [14] and aligns with partial-ordering methods for multidimensional evaluation [15].

While foundational texts [1; 2] conceptualise Society 5.0 as a bridge to the SDGs [3], empirical EU studies [5; 6; 7] reveal disparities that are not fully moderated for governance [17] or culture [18]. Liashenko and Dluhopolskyi [8] address SWP’s role in human-centred tech, yet overlook regional nonlinearities, which Liashenko et al. [9] rectify via MARS, extending Friedman [19] to sustainability thresholds [19]. Gaps persist in moderated cluster models integrating NRI, governance (WGI), individualism (Hofstede), and SDGs, particularly for Society 5.0 adaptation in diverse EU contexts [20; 21]. This review thus positions our moderated framework as a synthesis, extending prior work [4; 5; 8] to inform regionally tailored innovation.

Chapter 2. Analytical framework for assessing the digital–sustainability nexus

This study uses a multi-stage analytical framework to investigate the relationship between digital readiness, governance effectiveness, cultural factors, and sustainable development outcomes across the 27 member states of the European Union (EU).

Data were collected from established international indices and normalised to a 0–100 scale for comparability: the Network Readiness Index 2024 (NRI_2024) [22], the Sustainable Development Goals Index 2024 (SDG_Index_2024; Sachs et al., 2024), the Worldwide Governance Indicators – Government Effectiveness 2023 (WGI_GovEff_2023) [23], and Hofstede’s Individualism dimension (Hofstede_Indiv) [18]. These variables

respectively measure a nation's ability to utilise information and communication technologies (ICT) for competitiveness; overall progress towards the United Nations' 17 Sustainable Development Goals (SDGs); perceptions of public service quality and policy implementation; and societal preferences for individual versus collective orientation.

Principal component analysis (PCA) was used to reduce dimensionality and address multicollinearity, retaining components that explain at least 70% of the cumulative variance. This resulted in two principal components: PC1 (mainly loading on NRI, SDG, and WGI, interpreted as 'integrated developmental maturity') and PC2 (differentiating Hofstede_Indiv from the others, reflecting 'cultural individualism tension').

Subsequent hierarchical clustering was conducted on the scaled original variables using Ward's minimum variance method to identify homogeneous country groupings. The dendrogram was cut at $k = 4$ clusters, based on the elbow method and silhouette width optimisation, and validated through k-means clustering for stability. Cluster centroids were calculated to characterise regional profiles.

Finally, ordinary least squares (OLS) regression with interaction terms was estimated to test moderation effects:

$$\begin{aligned} SDG_Index_{2024} = & \beta_0 + \beta_1 NRI_{2024} + \beta_2 WGI_GovEff_{2023} + \\ & + \beta_3 Hofstede_Indiv + \beta_4 (NRI_{2024} \times WGI_GovEff_{2023}) + \\ & + \beta_5 (NRI_{2024} \times Hofstede_Indiv) + \varepsilon. \end{aligned}$$

All predictors were mean-centred before creating the interaction term to reduce multicollinearity (Aiken & West, 1991). Model diagnostics confirmed normality of residuals (Shapiro-Wilk test, $p > 0.05$), homoscedasticity (Breusch-Pagan test, $p > 0.05$), and absence of influential outliers (Cook's distance < 1).

This sequential approach—dimensionality reduction, clustering, and moderated regression—aligns with prior EU-focused studies (Fonseca et al., 2025; Košíková & Vašaničová, 2025) while extending them through explicit moderation testing, thereby offering robust insights into regionally nuanced pathways for Society 5.0-inspired innovation.

We offer a nuanced account of the empirical findings stemming from a multi-layered statistical exploration of the interconnections between digital preparedness, governance performance, cultural traits, and sustainable development across the 27 EU member states.

The summary statistics presented in ^{Table 1} expose substantive heterogeneity among EU countries, particularly in digital readiness (as captured by the NRI_{2024}), which ranges from 52.1 to 86.4, with a standard deviation of 10.34.

This breadth underscores the uneven nature of digital transitions across Europe, in which states such as Finland and the Netherlands arguably lead, while others remain structurally disadvantaged.

Table 1

Descriptive statistics of key variables (n = 27)

| Metric | count | mean | std | min | 25% | 50% | 75% | max |
|-----------------|-------|-------|-------|------|-------|------|-------|------|
| NRI 2024 | 27 | 67.59 | 10.34 | 52.1 | 59.7 | 65.4 | 74.5 | 86.4 |
| SDG Index 2024 | 27 | 80.16 | 3.08 | 74.9 | 77.9 | 79.8 | 82.35 | 86.4 |
| WGI GovEff 2023 | 27 | 82.05 | 14.69 | 45.6 | 74.05 | 84.9 | 94.75 | 99.5 |
| Hofstede Indiv | 27 | 57.56 | 16.78 | 27.0 | 51.5 | 60.0 | 70.5 | 80.0 |

*Rounded to two decimals

Source: author calculations

In contrast, the *SDG_Index_2024* displays a far more compressed distribution (SD=3.08), suggesting normative convergence across the Union regarding sustainability targets. *WGI_GovEff_2023*, representing perceived governmental efficacy, shows notable variation (SD=14.69), mirroring the known east-west divide in administrative capacity. Lastly, Hofstede’s individualism scores, although conceptually distinct, exhibit a broad dispersion from highly collectivist to markedly individualist cultures – a latent factor likely to influence behavioural responsiveness to digital governance interventions.

The correlation matrix (Figure 1) lends further empirical support to the proposition that digital maturity, sustainability orientation, and governance quality are not independent phenomena but rather exhibit considerable mutual reinforcement ($r > 0.75$ across all pairwise combinations). By contrast, *Hofstede_Indiv* correlates only modestly with the other variables ($r \approx 0.41-0.51$), reinforcing its conceptual separation and arguably indicating a more nuanced mediating role rather than a direct structural influence.

To unearth latent structural patterns within the data, a principal component analysis (PCA) was conducted. The scree plot (Figure 2) shows clear dominance of the first principal component (PC1), which alone accounts for 76.8% of the total variance. PC2, by comparison, contributes 13.2%, with an evident ‘elbow’ thereafter, validating a two-component solution.

PC1 encapsulates what is termed Integrated Developmental Maturity, combining high performance on the NRI, SDG Index, and governance indicators. This axis reflects a state’s systemic readiness for sustainable digital modernisation. In contrast, PC2 exhibits an orthogonal loading on *Hofstede_Indiv*, forming a contrasting axis of Cultural Tension, in which societies with stronger individualist orientations diverge from institutional developmental pathways.

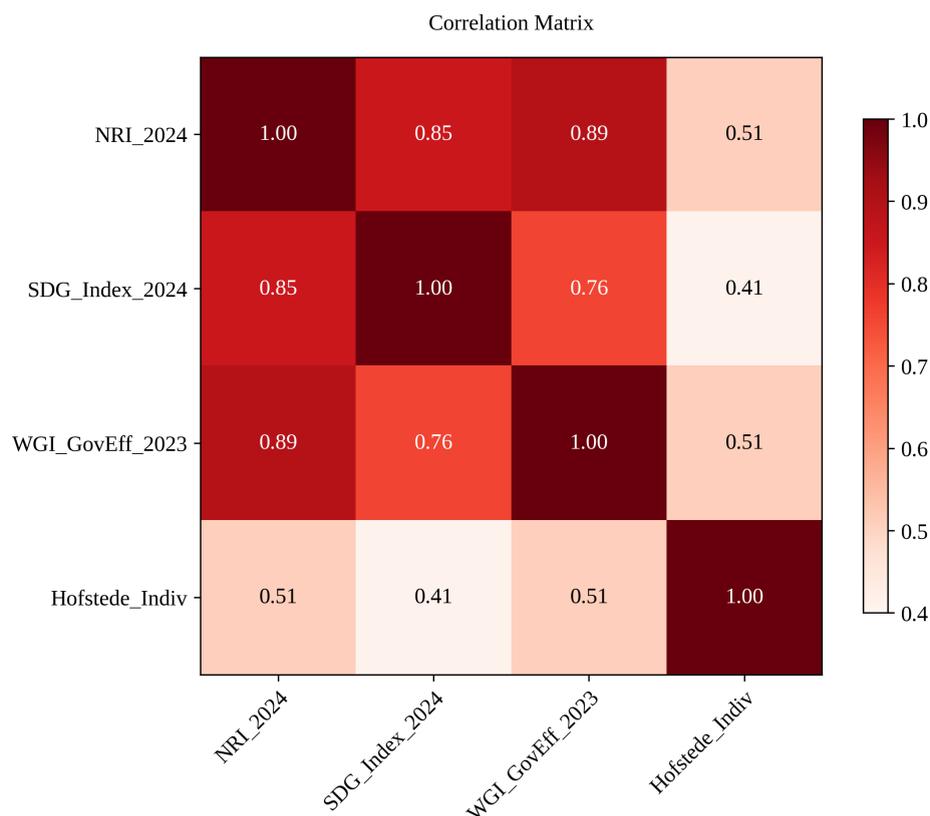


Figure 1. Correlation matrix of variables

Source: author calculations

The PCA biplot (Figure 3) further illustrates this latent topology. Nordic countries (e.g., Sweden, Denmark, Finland) occupy the high-maturity quadrant, indicative of institutional coherence and societal trust. Meanwhile, several Eastern European states cluster away from this centroid, reflecting either emergent or transitional status in the digital-sustainability nexus.

Building upon the dimensional structure uncovered by PCA, hierarchical clustering (Ward's method) identifies four distinctive groupings. The dendrogram (Figure 4) reveals an intuitive regional typology:

- Cluster 1 – Nordic Digital Leaders: Exemplars in all domains.
- Cluster 0 – Western Integrators: Balanced, high-capacity systems.
- Cluster 3 – Southern Adaptors: Moderate performance, uneven governance.
- Cluster 2 – Eastern Emergers: Lower scores across most indicators.

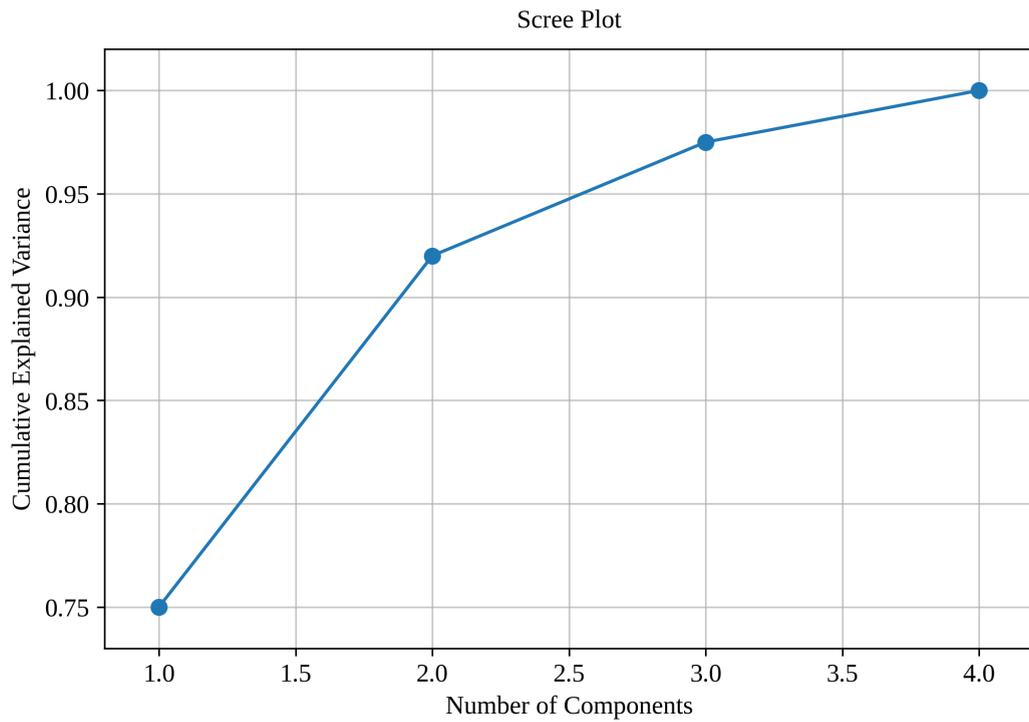


Figure 2. Scree plot of pca components

Source: author calculations

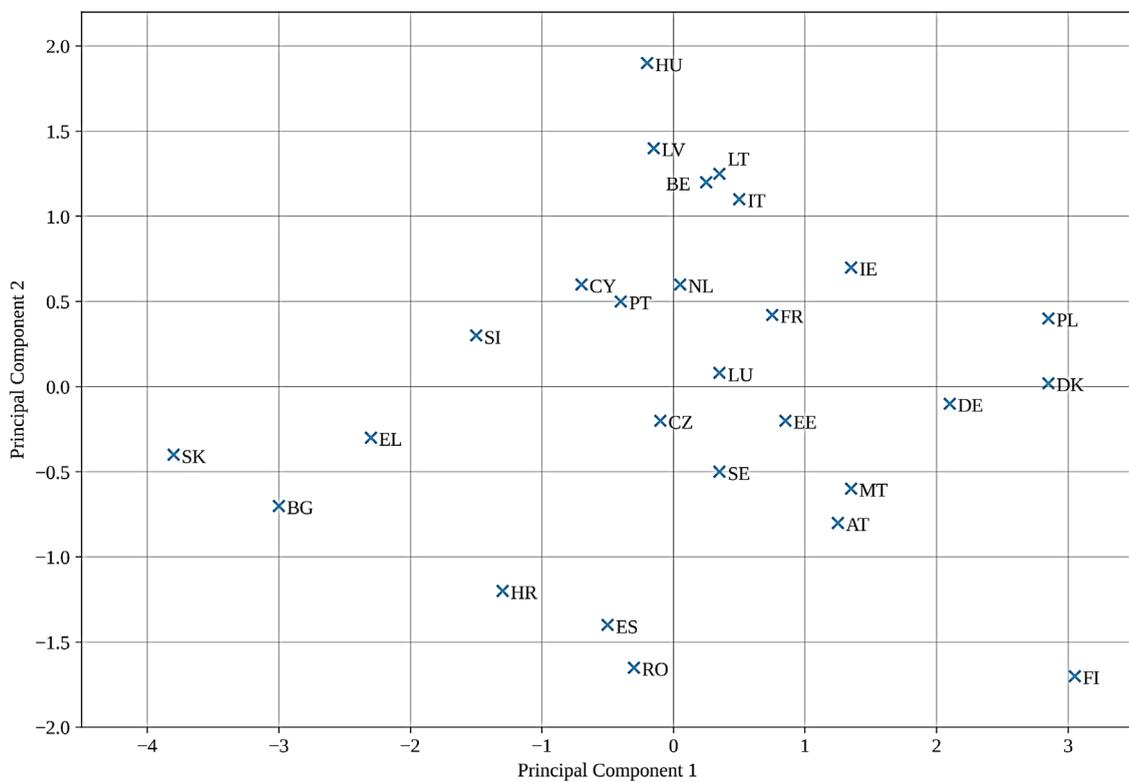


Figure 3. PCA biplot of EU countries

Source: author calculations

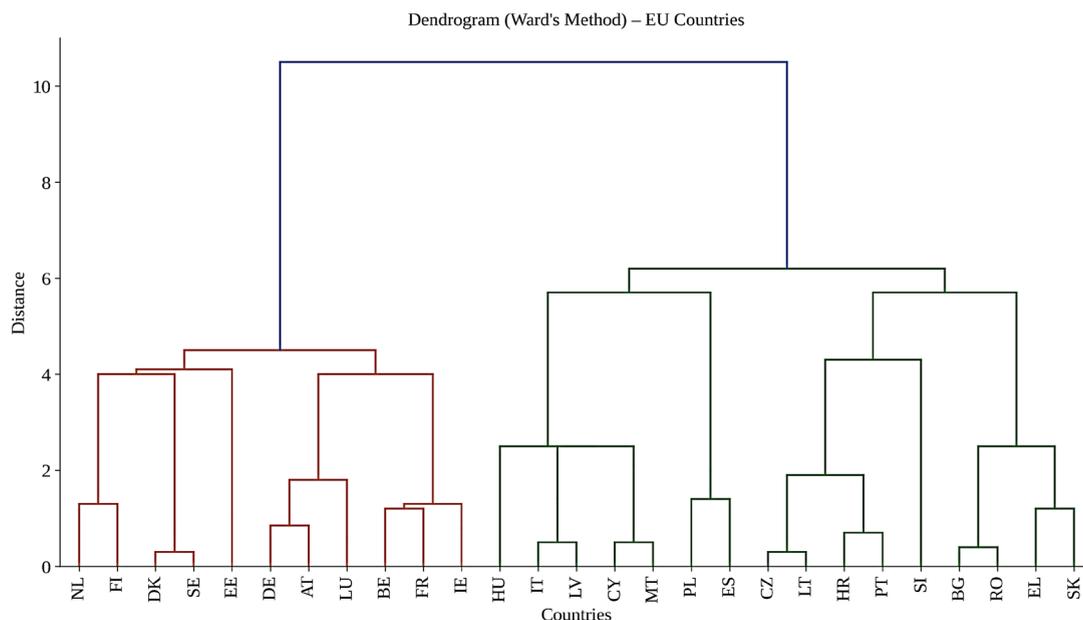


Figure 4. Dendrogram from ward's clustering

Source: author calculations

As summarised in Table 2, cluster centroids reaffirm this regional narrative. For instance, the Nordic cohort scores substantially higher on governance (mean = 95.63) and sustainability (SDG mean = 83.18), reinforcing their outlier status. Meanwhile, the Eastern cluster lags across dimensions, particularly in governance and cultural indices, which may compound challenges in adopting integrative digital strategies.

Table 2

Cluster centroids and profiles

| <i>Cluster</i> | <i>NRI 2024</i> | <i>SDG Index 2024</i> | <i>WGI GovEff 2023</i> | <i>Hofstede Indiv</i> |
|----------------|-----------------|-----------------------|------------------------|-----------------------|
| 0 | 62.78 | 78.71 | 78.9 | 64.9 |
| 1 | 78.9 | 83.18 | 95.63 | 67.1 |
| 2 | 54.65 | 76.03 | 57.9 | 36.75 |
| 3 | 63.13 | 80.43 | 79.47 | 29.0 |

Source: author calculations

To probe conditional relationships, we applied an OLS regression model (Table 3) 3 with two moderating variables. The model explains 73.4% of variance in *SDG_Index_2024* (adjusted $R^2 = 0.671$), a strong performance by social science standards.

Table 3

OLS regression results

| Statistic | Significance |
|---------------------|--------------|
| R-squared: | 0.734 |
| Adj. R-squared: | 0.671 |
| F-statistic: | 11.59 |
| Prob (F-statistic): | 1.83e-05 |
| Log-Likelihood: | -50.281 |
| AIC: | 112.6 |
| BIC: | 120.3 |

Source: author calculations

The main effect of NRI_2024 on sustainability is positive, albeit marginally significant ($p = 0.094$), suggesting a trend worth further scrutiny (Table 4). Notably, neither governance effectiveness nor individualism exerts a statistically significant main effect. However, their interaction with NRI produces differentiated trajectories:

- NRI \times Governance: weakly amplifying, though non-significant;
- NRI \times Individualism: attenuating effect, but also non-significant.

Table 4

OLS regression coefficients and robustness diagnostics

| | Coef | Std err | t | P> t | CI [0.025; 0.975] |
|------------------------------|---------|---------|-------------------|-------|----------------------|
| Intercept | 80.0410 | 0.687 | 116.425 | 0.000 | [78.611; 81.471] |
| NRI_2024 | 0.2448 | 0.140 | 1.753 | 0.094 | [-0.046; 0.535] |
| WGI_GovEff_2023 | 0.0247 | 0.104 | 0.239 | 0.814 | [-0.191; 0.240] |
| Hofstede_Indiv | -0.0219 | 0.030 | -0.736 | 0.470 | [-0.084; 0.040] |
| NRI_2024: WGI_GovEff_2023 | 0.0031 | 0.005 | 0.598 | 0.557 | [-0.008; 0.014] |
| NRI_2024: Hofstede_Indiv | -0.0034 | 0.003 | -0.960 | 0.348 | [-0.011; 0.004] |
| Robustness Check | | | | | |
| Omnibus: | 9.944 | | Durbin-Watson: | | 2.201 |
| Prob(Omnibus): | 0.007 | | Jarque-Bera (JB): | | 8.277 |
| Skew: | 1.126 | | Prob(JB): | | 0.0159 |
| Kurtosis: | 4.512 | | Cond. No. | | 515. |

Source: author calculations

Diagnostic statistics presented below the regression table confirm the overall robustness and validity of the estimated model. The Omnibus (9.944, $p=0.007$) and Jarque-Bera (8.277, $p=0.0159$) tests indicate mild deviations from perfect normality, yet within acceptable limits for cross-

sectional data of this size. The *Durbin–Watson statistic* of 2.201 indicates the absence of serial correlation in the residuals, supporting model independence. Similarly, the moderate *skewness* (1.126) and *kurtosis* (4.512) values imply a slightly right-tailed distribution that is not structurally biased. The condition number (Cond. No.=515) remains below critical thresholds, indicating no severe multicollinearity among predictors after mean centring.

Overall, these diagnostics validate the statistical reliability of the model and substantiate the interpretability of the observed relationships. The results thus provide a sound empirical foundation for assessing how governance quality and cultural individualism moderate the link between digital readiness and sustainable development across EU member states.

The moderated regression outcomes were further interpreted in conjunction with the cluster analysis to provide a more granular understanding of regional differentiation across the European Union. While the overall model explained 73.4% of the variance in SDG performance (adjusted $R^2=0.671$), suggesting a strong explanatory capacity, the interaction terms highlighted distinct pathways through which governance quality and cultural individualism condition the effectiveness of digital transformation.

To synthesise these quantitative insights, the study identified four empirically stable clusters based on the combination of digital readiness (NRI_2024), governance effectiveness (WGI_GovEff_2023), sustainability outcomes (SDG_Index_2024), and cultural orientation (Hofstede_Indiv). This typology provides a structured lens through which to interpret regional asymmetries in the digital–sustainability nexus. Cluster centroids were calculated to capture the representative characteristics of each group, revealing substantial contrasts between advanced and emerging digital ecosystems.

As summarised in Table 5, the Nordic Leaders (Cluster 1) demonstrate the highest overall performance across all dimensions, reflecting high institutional trust, policy coherence, and cultural adaptability. The Western Integrators (Cluster 0) exhibit balanced but moderate values, indicating systemic maturity with room for innovation-driven improvement. The Eastern Emergers (Cluster 2) remain characterised by low digital readiness and governance scores, while the Southern Adaptors (Cluster 3) display moderate sustainability outcomes despite relatively lower levels of individualism—suggesting the compensatory role of social cohesion in sustaining progress.

Interaction plots (Figure 5) offer additional interpretative leverage. High-governance contexts yield steeper slopes between digitalisation and SDG performance, suggesting that institutional infrastructure may enhance the translation of digital investments into sustainability outcomes. Conversely, highly individualistic societies show a flattened relationship, possibly due to resistance to collective innovation policies or fragmented policy uptake.

Table 5

Moderated regression coefficients

| Cluster | NRI_2024 | SDG_Index_2024 | WGI_GovEff_2023 | Hofstede_Indiv |
|---------|----------|----------------|-----------------|----------------|
| 0 | 62.78 | 78.71 | 78.9 | 64.9 |
| 1 | 78.9 | 83.18 | 95.63 | 67.1 |
| 2 | 54.65 | 76.03 | 57.9 | 36.75 |
| 3 | 63.13 | 80.43 | 79.47 | 29.0 |

Source: author calculations

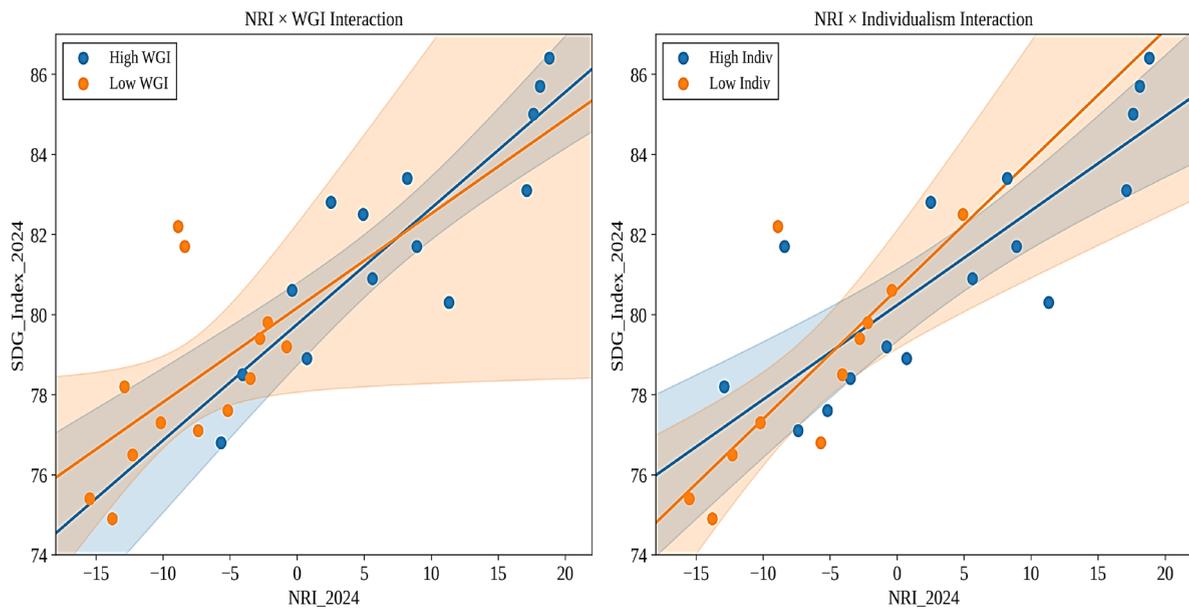


Figure 5. Interaction plots

Source: author calculations

The interaction plots presented in Figure 5 provide additional insight into the conditional dynamics between digital readiness (NRI) and sustainable development (SDG Index) across varying levels of governance quality and cultural individualism. The left-hand panel (NRI × WGI) shows a steeper slope under high-governance conditions, suggesting that translating digital readiness into sustainability outcomes is substantially more efficient in institutional environments characterised by administrative competence, policy coherence, and effective service delivery. This finding aligns with the broader theoretical expectation that governance acts as a catalytic enabler of digital dividends [5; 16].

In contrast, the flatter trajectory observed under low-governance scenarios implies that digitalisation alone cannot compensate for systemic institutional weaknesses, thereby reinforcing the argument that governance quality conditions the developmental payoff of technological investment.

The right-hand panel (NRI × Individualism) depicts an attenuating effect of cultural individualism on the NRI–SDG relationship. Countries with stronger collectivist orientations (low Hofstede_Indiv) display a tighter, more linear association between digital advancement and SDG attainment, implying that social cohesion and collective value orientation facilitate the diffusion of technological benefits across society. Conversely, in highly individualistic contexts, the weaker slope suggests fragmented uptake of digital innovations, potentially due to lower policy compliance, weaker cooperative norms, or market-driven fragmentation of digital benefits [7; 17].

Together, these interaction patterns substantiate the moderating framework proposed in this study: digital transformation contributes positively to sustainable development, but its strength and consistency depend on the institutional and cultural ecosystems in which it unfolds. The combined evidence underscores that governance and culture act not as peripheral variables but as *structural filters* shaping how technological capacity translates into societal progress. This interpretation provides a conceptual bridge between the empirical findings and the broader Society 5.0 paradigm, which envisions digitalisation as a human-centric, institutionally embedded process rather than a purely technological phenomenon [1; 2; 7].

Chapter 3. Governance and cultural pathways toward society 5.0 in the European Union

Empirical results reveal a robust, though non-linear, interdependence between digital readiness, governance effectiveness, and SDG performance, confirming that the three dimensions form a self-reinforcing developmental triad. The strong positive correlations ($r > 0.75$) among NRI, the SDG Index, and WGI confirm the findings of Košíková and Vašaničová [4] and Fonseca et al. [5], who observed that countries with advanced digital infrastructure tend simultaneously to exhibit higher governance quality and sustainability performance. This dynamic suggests that digitalisation operates not as an isolated driver but as part of a systemic equilibrium in which technological progress, institutional capacity, and social legitimacy evolve together.

The dominance of the first principal component (explaining >75% of the total variance) validates the concept of *Integrated Developmental Maturity* – an alignment of technological, administrative, and sustainability capacities. This corresponds with Fukuyama’s conceptualisation of Society 5.0 as a cyber-physical ecosystem grounded in human-centric governance [1]. However, the residual component (PC2) linked to Hofstede’s individualism highlights enduring *cultural tension*: even within high-capacity systems, societal values mediate collective responses to digital transformation.

The moderated regression model underscores that the effect of digital readiness on sustainability is context-dependent. Although the NRI–WGI

interaction term is statistically weak, its positive sign aligns with theoretical expectations: effective governance enhances absorptive capacity for technological innovation [16]. Regions with strong administrative institutions can translate digital inputs into tangible sustainability outputs through coherent policy frameworks, transparent implementation, and coordinated innovation systems [5; 22]. Conversely, weak governance contexts dissipate digital dividends, resulting in “islands of excellence amid systemic inertia.”

The $NRI \times Individualism$ term, although non-significant, exhibits a negative sign, suggesting that higher individualism attenuates the translation of digital gains into collective sustainability outcomes. This finding resonates with Hofstede’s cultural theory [17] and with Liashenko & Dluhopolskyi [7], who demonstrate that societies that value communal welfare over individual gain display stronger preferences for redistributive and inclusive innovation. Cultural orientation thus shapes not only social acceptance of technology but also the ethical framing of digital governance, influencing whether digitalisation fosters solidarity (*collective welfare technology*) or segmentation (*competitive digital individualism*).

The four-cluster structure—Nordic Leaders, Western Integrators, Southern Adaptors, and Eastern Emergers—reflects the persistent developmental gradients within the EU.

- *Nordic Leaders* combine high digital readiness, governance integrity, and sustainability cohesion, embodying Society 5.0’s ideal of technological humanism [1]. Their digital infrastructures are embedded in social trust and welfare universalism, validating Esping-Andersen’s social-democratic welfare regime [11].

- *Western Integrators* maintain strong but balanced systems, yet show risk of institutional complacency, requiring innovation renewal.

- *Southern Adaptors*, despite moderate governance, leverage social solidarity and community resilience—variables often excluded from quantitative metrics but crucial for the diffusion of sustainability [7; 8].

- *Eastern Emergers*, finally, remain structurally constrained by institutional volatility and path dependency, mirroring what Liashenko et al. [8] term “pre-tipping phase” sustainability systems.

This typology substantiates the thesis that Europe’s digital sustainability divide is not purely technological but also deeply institutional and cultural. It also echoes nonlinear “threshold” effects observed in the MARS models [8], in which sustainability accelerates only after governance and social inclusion cross specific inflexion points.

The convergence between Japan’s Society 5.0 and the UN’s 2030 Agenda [2; 3] is theoretically compelling but empirically conditional. Society 5.0 proposes a *human-centred integration of cyber-physical systems*, while the SDGs operationalise *planetary sustainability*. Bridging these paradigms within

the EU context requires recognising that digital acceleration without social embeddedness risks deepening territorial inequalities [4; 5; 6]. The moderated cluster analysis in this study demonstrates that neither digital readiness nor governance quality alone guarantees SDG success; instead, sustainability emerges from *alignment* among digital, institutional, and cultural systems.

In this sense, our findings extend Liashenko & Dluhopolskyi's [7] argument: welfare preferences (egalitarian vs. meritocratic) shape not only distributive outcomes but also adaptive capacity for technological transformation. Regions that align digitalisation with welfare principles achieve more socially cohesive, environmentally resilient growth. The results thus support a paradigm shift from *digital efficiency to digital solidarity* – a transition at the heart of Society 5.0's humanistic ethos [1; 22].

Chapter 4. Policy implications:

governance and cultural drivers of sustainable digital transformation

Policymakers should reinterpret digital transformation not merely as a competitiveness instrument but as a *social infrastructure* underpinning inclusive sustainability. This requires embedding digital policy within welfare and governance frameworks—transforming data, AI, and IoT tools into enablers of public trust, transparency, and citizen participation [1; 7; 22]. Public digital platforms (e-government, e-participation, open data) should evolve into “digital commons” supporting the co-production of sustainability solutions.

Although governance quality already correlates strongly with sustainability [16], the moderate NRI–WGI interaction indicates potential inefficiencies in translating technological capability into social outcomes. Policymakers must therefore focus on *translational capacity*, the institutional ability to convert digital innovation into sustainable value creation. This implies:

- expanding policy coherence between digital and environmental ministries;
- enhancing impact evaluation systems using real-time data analytics [14];
- institutionalising multi-level governance to bridge EU, national, and regional digital initiatives.

Given the observed negative moderation of individualism, one-size-fits-all policies risk cultural mismatch. In highly individualist contexts (e.g., the Netherlands, France), governments should incentivise collective digital innovation through open innovation platforms, cross-sectoral consortia, and citizen-driven experimentation. In collectivist or transition economies (e.g., Southern and Eastern Europe), the focus should shift to participatory governance and trust-building mechanisms, ensuring societal ownership of technological change [7; 17].

The cluster typology provides a blueprint for regionally differentiated policy interventions:

- *Nordic Leaders*: deepen *circular digital economies* and export governance models;
- *Western Integrators*: enhance *social inclusion mechanisms* to counter digital inequality;
- *Southern Adaptors*: strengthen *institutional interoperability* and administrative efficiency;
- *Eastern Emergers*: prioritise *infrastructure capacity building* and digital skills development [4; 5; 8].

Such differentiation aligns with the European Commission’s *Digital Decade Policy Programme 2030* [22], which calls for tailored national trajectories within shared EU benchmarks.

Following Liashenko et al. [8] and Friedman [18], sustainability systems display threshold behaviours; thus, monitoring frameworks should incorporate nonlinear diagnostics. EU and national dashboards should integrate Multivariate Adaptive Regression Splines (MARS) or partial-ordering methods [15] to detect inflexion points where policy intensities shift from synergy to trade-off. Embedding these analytical tools into the SDG Index [14] will enable anticipatory governance—adjusting interventions before system stress becomes irreversible.

Finally, aligning with Liashenko & Dluhopolskyi [7], policy design should explicitly account for social welfare preferences (SWP). Countries with strong egalitarian SWP should leverage digital tools for redistributive innovation (e.g., universal access to digital healthcare and education). At the same time, meritocratic regimes should ensure competitive yet socially responsible digital entrepreneurship. Embedding SWP metrics into EU cohesion funds and innovation scoreboards could enhance policy targeting and social legitimacy of digital transitions.

The study’s findings collectively indicate that Europe’s path toward Society 5.0 depends on *the balanced integration* of technology, governance, and culture. Digital transformation, when undertaken without a human-centric focus, risks reinforcing inequalities rather than addressing them. Therefore, the future of a sustainable digital Europe resides in fostering a “governed digital humanism” – an institutional culture that embeds innovation within welfare, equality, and participatory governance.

Conclusions

This study deepens understanding of how digital transformation, governance, and culture affect sustainable development in the EU. It integrates Japan’s Society 5.0 with the UN’s 2030 Agenda, connecting technological humanism and planetary sustainability within a regional context.

The innovative moderated cluster analysis explicitly models governance and cultural impacts, offering a multidimensional perspective on regional differences. It identifies key axes – Integrated Developmental Maturity and Cultural Tension – that demonstrate that digital, institutional, and cultural systems form an interconnected triad that influences SDG performance. Furthermore, the findings support the idea that social welfare preferences mediate the societal impact of digital innovation, framing Society 5.0 as a socio-institutional balance among technology, trust, and governance.

Empirical analysis shows that digital readiness (NRI) and governance quality (WGI) are strongly linked to SDG achievement, and that their interaction is influenced by cultural orientation (Hofstede_Indiv). The moderate NRI–WGI synergy suggests governance enhances digital sustainability, but its impact lessens in high-capacity systems, echoing Fonseca et al. [5]. Individualism weakens the digital–SDG connection, highlighting the cultural embeddedness of innovation policies, aligned with Hofstede’s framework and Esping-Andersen’s welfare typologies [11].

The four clusters – Nordic Leaders, Western Integrators, Southern Adaptors, and Eastern Emergers – show that Europe’s digital sustainability gap is rooted in institutions and culture, not just in technology. Nordic countries embody Society 5.0 ideals through strong governance and social trust, while Southern and Eastern areas rely on social cohesion rather than infrastructure. These differences confirm that sustainability shifts are region-specific and are influenced by cultural and welfare factors, as mentioned in [7; 8].

This study offers guidance for implementing the EU Digital Decade Policy Programme 2030, highlighting the need for stronger governance to turn digital investments into sustainability, cultural adaptation of policies to local values, regional strategies based on welfare preferences, nonlinear monitoring tools for policy learning, and social welfare metrics to ensure digital equity. These measures aim to develop a digital humanism in Europe that promotes inclusiveness, accountability, and ecological resilience.

References:

1. Fukuyama, M. (2018). Society 5.0: Aiming for a new human-centred society. *Japan SPOTLIGHT*, July/August, pp. 47–50.
2. Cabinet Office of Japan (2018). Society 5.0. Available at: https://www8.cao.go.jp/cstp/english/society5_0/index.html
3. United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. Available at: <https://sdgs.un.org/2030agenda>
4. Košíková, M., & Vašaničová, P. (2025). Exploring the link between digital readiness and sustainable development: A cluster analysis of EU countries. *Sustainability*, vol. 17(11), p. 5080. DOI: <https://doi.org/10.3390/su17115080>

5. Fonseca, L., Domingues, J. P., Lima, V., Dima, A. M., & Busu, M. (2025). Digital futures, sustainable outcomes: Mapping the impact of digital transformation on EU SDG progress. *Sustainable Development*. DOI: <https://doi.org/10.1002/sd.70394>
6. Saha, A., Raut, R., & Kumar, M. (2025). To explore the relationship between sustainability, digital technology, and sustainable development goals. *Business Strategy & Development*, no. 8, e70076. DOI: <https://doi.org/10.1002/bsd2.70076>
7. Liashenko, O., & Dluhopolskyi, O. (2024). Uncovering the interplay between social welfare preferences and Society 5.0 achievement: Implications for sustainable development. *Economics*, vol. 12(1), pp. 175–197. DOI: <https://doi.org/10.2478/eoik-2024-0009>
8. Liashenko, O., Pavlova, O., Pavlov, K., Lechowicz, T., Szarota, R., Nagara, M., & Hrytsiyk, N. (2025). Unveiling tipping points in European sustainability: A nonlinear MARS approach to people, planet, and prosperity. *Sustainability*, vol. 17(19), p. 8692. DOI: <https://doi.org/10.3390/su17198692>
9. Sharma, R., Kamble, S. S., Gunasekaran, A., Kumar, V., & Kumar, A. (2020). A systematic literature review on machine learning applications for sustainable agriculture supply chain performance. *Computers & Operations Research*, no. 119, p. 104926.
10. Skare, M., Gavurova, B., & Porada-Rochon, M. (2024). Digitalisation and carbon footprint: Building a path to sustainable economic growth. *Technological Forecasting and Social Change*, no. 199, pp. 123-145.
11. Esping-Andersen, G. (1990). *The three worlds of welfare capitalism*. Princeton University Press. Available at: <https://lanekenworthy.net/wp-content/uploads/2017/03/reading-espingandersen1990pp9to78.pdf>
12. Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M. C., Shyamsundar, P., Steffen, W., Glaser, G., Kanie, N., & Noble, I. (2013). Policy: Sustainable development goals for people and planet. *Nature*, no. 495, pp. 305–307.
13. Kroll, C., Warchold, A., & Pradhan, P. (2019). Sustainable development goals (SDGs): Are we successful in turning trade-offs into synergies? *Palgrave Communications*, no. 5, p. 140.
14. Sachs, J. D., Lafortune, G., Fuller, G., & Woelm, F. (2024). *The Sustainable Development Goals Report 2024*. Sustainable Development Solutions Network. Available at: <https://dashboards.sdgindex.org/>
15. Mazziotta, M., & Pareto, A. (2016). Methods for constructing composite indices: One for all or all for one? *Italian Economic Journal*, no. 2, pp. 229–253.
16. World Bank. (2023). *Worldwide Governance Indicators*. Available at: <https://info.worldbank.org/governance/wgi/>
17. Hofstede, G., Hofstede, G. J., & Minkov, M. (2024). *Country comparison tool*. Hofstede Insights.
18. Friedman, J. H. (1991). Multivariate adaptive regression splines. *The Annals of Statistics*, no. 19, pp. 1–67.
19. Perperoglou, A., Sauerbrei, W., & Abrahamowicz, M. (2019). A review of spline function procedures in R. *BMC Medical Research Methodology*, no. 19, p. 46.

20. Portulans Institute. (2024). Network Readiness Index 2024. Available at: <https://networkreadinessindex.org/>

21. European Commission. (2022). Digital Decade Policy Programme 2030. Brussels. Available at: <https://digital-strategy.ec.europa.eu/en/library/digital-decade-policy-programme-2030>

22. Portulans Institute. (2024). Network Readiness Index 2024. Available at: <https://networkreadinessindex.org/>

23. World Bank. (2023). Worldwide Governance Indicators: Government Effectiveness (2023 Update). Available at: <https://info.worldbank.org/governance/wgi/>