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A Synergistic Model of Technological Capacity, Institutions, and Culture in the Transition Towards Society 5.0: Cross-Country Evidence

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Abstract

This study elucidates global variation in achieving Society 5.0 objectives by identifying the foundational requirements, thresholds, and synergistic configurations of technological and AI capacity, institutional quality, and cultural values across nations. The research develops a novel conceptual model that integrates core determinants while accounting for country-specific conditions in the transition towards a human-centered society. Utilizing a harmonized dataset encompassing 102 countries, this study employs hierarchical multiple regression and three-way interaction modeling to evaluate the direct, conditional, and higher-order effects of technological readiness and its interaction with institutional and cultural values on Human-Centered Outcomes (HCO). The empirical results demonstrate that technological advancement and AI readiness alone are insufficient to generate meaningful societal progress. Instead, institutional quality emerges as the most robust predictor, significantly amplifying the relationship between digital capacity and human-centered outcomes. Among cultural dimensions, power distance exhibits the most pronounced constraining effect, while individualism and long-term orientation display consistent but statistically weaker patterns. These findings elucidate the paradox of divergent national outcomes arising from AI integration, leading to a new country taxonomy based on empirical proximity to the Society 5.0 benchmark. Ultimately, the article challenges technocentric narratives and advances a co-evolving concept of socially embedded change, providing actionable insights into how technological, institutional, and cultural pillars must be aligned to foster inclusive and well-being-oriented digital transformation.

Keywords:

Society 5.0; Digital Transformation; Technological Advancement; AI Readiness; Institutional Quality; Cultural Value Orientations; Human-Centered Development; Well-Being-Oriented Governance; Cross-Country Analysis; Hofstede's Dimensions.

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1- Introduction

The Society 5.0 concept, introduced in Japan's Fifth Science and Technology Basic Plan [1], reorients digital transformation from a technology-driven imperative towards a human-centered societal vision [2, 3]. The fusion of cyber- and physical space is intended to advance economic productivity while enabling responses to pressing social challenges such as population aging, environmental sustainability, and equitable access to services, ultimately enhancing collective well-being and systemic resilience [4–7]. Institutionalization in Japan specifically links digital innovation to sustainability, safety, and multidimensional welfare [3, 8, 9]. Globally, this aligns with OECD and UN assessments that position digital transformation as being integral to state capacity, economic competitiveness, and public service innovation [10–12]. The contemporary literature increasingly emphasizes the need for trustworthy, inclusive, and accountable governance, in which outcomes are measured in terms of equity, democratic legitimacy, and institutional coherence [13–16].

However, rhetorical convergence around digital transformation often masks a profound divergence in practice. Although countries increasingly adopt similar strategies for digitalization, AI, and smart governance, they differ markedly in their institutional implementation capacity, regulatory credibility, public trust, and the normative legitimacy of digitally mediated governance [17]. Comparative evidence confirms persistent cross-national disparities in the ability to translate digital capabilities into inclusive and socially beneficial outcomes [18, 19]. Technological capability alone is, therefore, insufficient. High levels of digital infrastructure [20] or AI readiness do not automatically yield stronger human-centered outcomes, such as social inclusion, institutional trust, or sustainability-aligned development. Furthermore, digital transformation can generate systemic risks, particularly where governance quality, accountability mechanisms, and inclusion safeguards remain weak. From a Society 5.0 perspective, the decisive issue is not technological deployment itself, but the socially legitimate and institutionally governable use of digital systems.

These conditional relationships reflect deep-seated structural differences across nations. Economic and legal institutions, including enforceable safeguards, implementation capacity, and regulatory credibility, determine whether digital systems generate public value or reinforce existing asymmetries [21]. Similarly, cultural values influence public trust, perceptions of legitimacy, and societal acceptance of accountable governance [22, 23]. While the influence of culture on innovation is well established [24, 25], existing research provides limited insight into how cross-national differences in cultural dimensions interact with digital transformation [26]. The rapid but uneven global diffusion of AI further underscores that technological capacity is a necessary but insufficient condition for achieving Society 5.0 goals [27–29].

1-1- Research Gaps

Recent research has conceptualized Society 5.0 as a development model in which technological innovation is harnessed to advance social well-being and quality of life [30–33]. However, the empirical literature remains fragmented across largely separate streams on technological readiness [34], institutional conditions [35], and cultural influences [36, 37]. This fragmentation limits the ability of existing research to explain how these determinants jointly shape human-centered outcomes [38, 39]. As a result, Society 5.0 risks being reduced to a technocratic modernization narrative: an extension of Industry 4.0 in which technological complexity is mistaken for social progress. Critical concerns, such as algorithmic bias and digital inequality [40–42], further underscore that meaningful societal outcomes depend on institutional regulation [43], social coordination, and ethically guided governance.

Operationalizing Society 5.0 as a human-centric paradigm faces significant empirical and conceptual constraints. Current studies frequently suffer from construct substitution, measuring societal well-being through technocentric proxies such as digital infrastructure. This approach conflates means with ends and treats technological sophistication as a substitute for genuine progress towards inclusive governance [44]. Without a clear distinction among technological capacity, institutional–legal governability, and societal well-being outcomes, cross-national comparisons risk underweighting governance, a problem compounded by fragmented global AI governance regimes that reduce indicator comparability [45]. Empirical work also tends to overlook the implementation gap by treating regulation as binary and neglecting administrative competence [46, 47]. Society 5.0 readiness, therefore, requires reconceptualization as the measurable capacity to implement accountable safeguards, rather than as a set of already achieved outcomes [48, 49].

Mapping national performance across these dimensions pinpoints implementation bottlenecks within Society 5.0, directing attention towards priorities for targeted policy interventions [50]. Developmental delays require explanations beyond boundary conditions or transient constraints [51]. The resulting insights establish a practical knowledge base for constructing a nuanced taxonomy of development trajectories [52]. Such an analytical design provides a structured foundation for evaluating multidimensional transformation processes, strengthening interpretive depth and analytical robustness in cross-national research.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature, introduces the author's conceptual model, and develops the study hypotheses. Section 3 details the research methodology, including data sources, variable operationalization, and analytical strategy. Section 4 presents the empirical results, including direct and interaction effects and robustness checks. Section 5 discusses the representative country profiles and the proposed country taxonomy, identifies the countries closest to Society 5.0, compares the main findings with prior research, and outlines their theoretical and policy implications. Finally, Section 6 summarizes the study's main conclusions and presents the limitations and directions for future research.

2- Conceptual Model and Hypothesis Development

2-1- Theoretical Foundations of Society 5.0: Towards Socio-Technical Convergence

The conceptual foundations for understanding Society 5.0 derive from three interrelated theoretical streams: technology acceptance, national innovation systems, and institutional theory. At the micro level, research on technology acceptance has evolved substantially since Davis's Technology Acceptance Model (TAM), identifying perceived usefulness and perceived ease of use as key predictors of adoption intentions [53]. Later extensions, including TAM2, TAM3, and the Unified Theory of Acceptance and Use of Technology (UTAUT), incorporated social influence, facilitating conditions, and individual differences as additional determinants of technology uptake [54, 55]. Collectively, models demonstrate technology adoption driven by interaction between user perceptions and contextual conditions, distinct from technical functionality alone. Originally designed to explain the adoption of distinct technologies as opposed to broad societal transitions, such approaches provide an important micro-level foundation by highlighting digital transformation as contingent, socially mediated, and institutionally embedded.

National innovation systems theory posits that technological transformation emerges from dynamic interactions among institutions, infrastructure, and cultural endowments varying systematically across countries [56]. The systems view rejects the notion that societal digitalization reduces to aggregated individual choices, instead foregrounding the co-evolution of technological capabilities, institutional arrangements, and collective behavioral patterns. Complementing this, institutional theory emphasizes large-scale technology adoption embedded within regulative, normative, and cultural-cognitive structures shaping both the availability of digital systems and the legitimacy of deployment. Institutional layers determine how technologies remain governed and experienced. Synthesising micro-level acceptance mechanisms with macro-level institutional and systemic dynamics enables a more nuanced analysis of Society 5.0 as a socio-technical convergence process conditioned by national technological readiness, governance quality, and cultural value orientations, separate from a uniform technological rollout.

Technological readiness plays a pivotal role in shaping adoption trajectories, spanning both individual dispositions and systemic preparedness. Parasuraman originally defined technology readiness as individuals' propensity to embrace and use new technologies, structured along four dimensions: optimism, innovativeness, discomfort, and insecurity [57]. At the societal level, readiness extends beyond psychological traits to encompass digital infrastructure maturity, regulatory structures, educational capacity, and organizational capabilities. Empirical studies confirm expansion: research on smart city initiatives shows that higher technological readiness strongly correlates with increased citizen engagement and digital service utilization. Similarly, the World Economic Forum's Network Readiness Index reveals robust associations between national readiness scores and successful digital transformation outcomes across 134 economies [58]. For Society 5.0, a vision integrating digital systems across all societal domains, foundational conditions become especially critical. Inadequate readiness at both the individual and institutional levels and superficial transition risks preclude the achievement of human-centric objectives.

Society 5.0 is conceptualized as a contingent socio-technical configuration emerging from the dynamic co-evolution of technological systems, institutional frameworks, and normative value structures. This perspective transcends technocentric paradigms of digital transformation by analytically decoupling technological advancement as an instrumental means from the teleological ends of societal development.

The analysis proceeds via a comparative assessment of international digital models (Table C1). Cross-national similarity in metrics, such as digitalization, AI adoption, smart governance, or sustainability, fails to imply equivalence in national trajectories with respect to institutional effectiveness, normative legitimacy, or human-centric performance. Transition remains an institutionally conditioned process, diverging from an unfolding technological trajectory. High levels of technological saturation and absent institutional balance intensify digitalization while simultaneously producing normative fragility. Strong institutional maturity lacking sufficient technological capacity limits transformative potential. At the national level, human-centric outcomes of digital transformation define observable macro-level societal and governance effects that emerge when technological and AI capabilities convert effectively, through enforceable institutional guarantees, into tangible improvements in well-being, inclusion, fairness, trust, and accountability. Against this backdrop, our research advances an alternative conceptualization of Society 5.0 as a normative–analytical ideal type that captures the degree of systemic alignment among digital capabilities, governance architecture, and human-development-oriented outcomes.

Figure 1 illustrates the integrated conceptualization of Society 5.0.

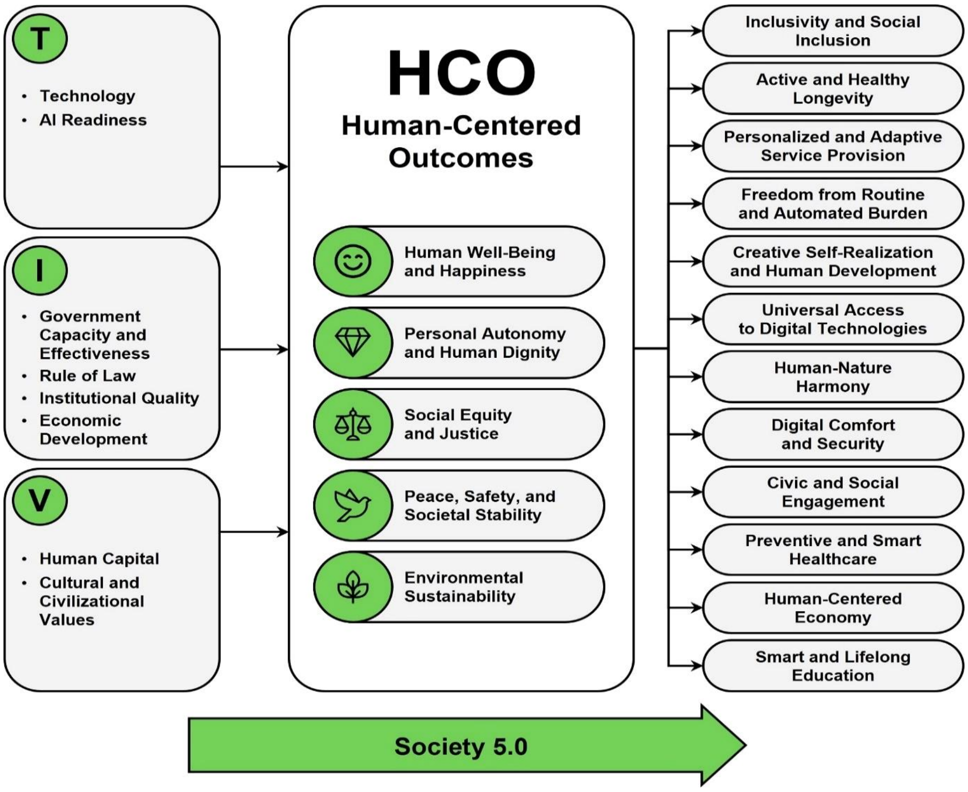

Figure 1. **Concept of a human-centered Society 5.0**

Theoretical argumentation presented above supports the formulation of the first hypothesis.

H1. *Higher national levels of technological and AI readiness are positively associated with human-centered digital transformation outcomes at the country level.*

Technological readiness defines feasibility, and economic-legal institutions determine governability, enforceability, accountability, and public legitimacy. Such capacity proves critical within human-centered digital development models, where inclusion, fairness, accountability, and rights-compatible implementation function as constitutive goals, distinct from secondary constraints. Stronger institutions enhance societal well-being by narrowing policy design-implementation gaps, strengthening accountability in digital technology deployment through robust oversight, risk governance, and redress mechanisms, and increasing governance predictability to foster public trust in digitally mediated systems. Higher institutional quality thus correlates positively with improved outcomes.

H2a: *More favorable economic conditions for resourcing and scaling socially oriented digital transformation are positively associated with human-centered digital transformation outcomes at the country level.*

H2b: *Higher quality of the legal-institutional environment for digital transformation, ensuring governability, accountability, and rights protection, is positively associated with human-centered digital transformation outcomes at the country level.*

H3. *Higher overall quality of institutions strengthens the positive relationship between national technological and AI readiness and the human-centered outcomes of digital transformation at the country level.*

Cross-national analysis within Society 5.0 requires recognizing that digital transformation outcomes diverge at comparable technological readiness levels due to culturally embedded models of accepting and governing digital change. Civilizational values function as contextual boundary conditions moderating the conversion of technological capacity and institutional governability into socially meaningful results, distinct from direct determinants of HCO.

2-2- Cultural Values as Boundary Conditions of Socio-Technical Transformation

Cultural values constitute historically rooted normative orientations shaping collective expectations regarding the legitimate boundaries of technological development, sources of political authority, and principles of social distribution. Such orientations reflect deep-seated cultural structures distinct from short-term political preferences or formal institutional arrangements. An analytical distinction remains essential: institutions refer to formalized rules, governance mechanisms, and enforcement systems, whereas values represent shared normative orientations shaping the perception, interpretation, and legitimization of those institutions. The effectiveness of institutions remains partly contingent upon value-based legitimacy.

Identical regulatory frameworks yield divergent outcomes across societies depending on levels of public trust, attitudes towards hierarchy, and tolerance for uncertainty. Cultural values function as contextual boundary conditions shaping the extent to which technological and institutional capacities translate into sustainable, human-centered outcomes. Culture can be decomposed into interconnected layers (national, regional, organizational, team, and individual) comprising material sublayers (institutional practices, formal rules, and artifacts) and immaterial sublayers (norms, values, and expectations). For Society 5.0, such architecture requires operationalization through concrete governance routines, including procurement standards, accountability mechanisms, redress procedures, transparency requirements, and enforceable safeguards. Practices are enacted through organizational routines and individual agency, yet remain bounded by national value orientations and within-country heterogeneity. National cultural value structures condition how technological and institutional readiness convert into diffusion-related manifestations and improvements in societal well-being.

Values influence socio-technical transformation through three interrelated mechanisms. First, cultural orientations configure public perceptions of data-driven governance, algorithmic decision-making, and digital platforms; this process determines whether digital integration is interpreted as a collective public good or a structural threat to individual rights and autonomy, contingent upon normative expectations of fairness and accountability. Second, orientations towards uncertainty shape the societal willingness to engage in technological experimentation, thereby driving the subsequent demand for robust safeguards, standards, and redress mechanisms. Third, attitudes towards hierarchy and the balance between individualism and collectivism inform preferred models of digital governance, ranging from centralized control to decentralized, participatory arrangements. Collectively, these mechanisms function as moderating factors that guide the trajectory of digital modernization rather than acting as deterministic forces.

Cultural dimensions offer a systematic lens for understanding how societal values influence technology acceptance and legitimacy perceptions across national contexts. The present analysis focuses on four dimensions from Hofstede's model as plausible moderators of the relationship between readiness and outcomes under the Society 5.0 logic, including individualism-collectivism (IDV), power distance (PDI), uncertainty avoidance (UAI), and long-term orientation (LTO). IDV reflects the extent to which societies prioritize individual autonomy over group embeddedness. In digital transformation contexts, more individualistic cultures tend to emphasize personal utility and autonomous choice, whereas collectivist societies place greater weight on social influence and collective benefit. For Society 5.0, which seeks to balance individual empowerment with societal well-being, this dimension critically shapes the negotiation of trade-offs between privacy and collective data-driven gains. Such trade-offs are perceived as legitimate only when underpinned by credible institutional safeguards.

H4. *A higher level of individualism strengthens the positive relationship between national technological and AI readiness and the human-centered outcomes of digital transformation at the country level.*

PDI, defined as the extent to which less powerful members of society accept unequal power distribution, shapes digital transformation through its influence on communication structures, decision-making hierarchies, and expectations of voice and contestability [59]. In societies characterized by high PDI frameworks**,** technology diffusion tends to follow top-down patterns, with innovations disseminating from authority figures to subordinates [60]. Agent-based modeling further shows that such societies exhibit more clustered social networks and restricted cross-stratum communication, which impedes information flow and slows innovation adoption during early and mid-stages [61]. For Society 5.0, which presupposes inclusive service legitimacy, citizen-facing accountability, and participatory governance, these hierarchical dynamics may undermine the conversion of technological and institutional readiness into trust, inclusion, and perceived fairness in algorithmic systems. Consequently, higher power distance is expected to negatively moderate the relationship between national readiness and HCO.

H5. *A higher level of power distance weakens the positive relationship between national technological and AI readiness and the human-centered outcomes of digital transformation at the country level.*

UAI reflects a society's tolerance for ambiguity and unstructured situations, directly shaping its receptivity to technological innovation with uncertain consequences [59]. In high-uncertainty-avoidance cultures, individuals exhibit greater resistance to novel technologies, demanding extensive guarantees, procedural clarity, and risk-mitigation mechanisms before adoption [62]. Jan et al. [63] identified UAI as a key predictor of perceived ease of use, with individuals in such contexts requiring stronger assurances about system reliability and usability. Although some studies note that uncertainty avoidance may facilitate later-stage diffusion, once early adopters validate a technology [61], Society 5.0 entails systemic, society-wide transformation rather than incremental innovation. Its implementation involves institutional redesign, data-intensive governance, and shifts in public-state relations, all of which generate high levels of perceived uncertainty. Under these conditions, risk-averse orientations are likely to inhibit broad-based engagement, delay regulatory adaptation, and reduce public trust in algorithmic systems. Consequently, higher national uncertainty avoidance is expected to negatively moderate the relationship between digital readiness and HCO, particularly in domains requiring citizen participation, institutional experimentation, and adaptive governance.

H6. *A higher level of uncertainty avoidance weakens the positive relationship between national technological and AI readiness and the human-centered outcomes of digital transformation.*

Cultural dimensions interact with technological readiness, shaping complex, society-specific adoption dynamics. Values moderate relationships between digital infrastructure and usage patterns [64]. UAI reflects intolerance for ambiguity and preference for structured environments, conditioning responses to systemic innovation. Agent-based simulations by He & Lee [61] demonstrate innovation characteristics significantly influencing diffusion speed and scale within high UAI contexts, exerting a minimal effect where UAI remains low. High UAI societies display heightened sensitivity to perceived risks inherent in large-scale digital transformation, exhibiting resistance to innovations with uncertain outcomes even when substantial technological infrastructure exists [65]. Society 5.0 entails deep integration of AI, data-driven governance, and cyber-physical systems, introducing novel uncertainties that inhibit public trust, delay regulatory adaptation, and constrain participatory engagement under high UAI. Comprehensive transformation with inherently ambiguous consequences reduces efficiency translating infrastructure investments into human-centered results, absent mitigation of cultural risk aversion through robust safeguards. Thus, higher national UAI negatively moderates the links between digital AI capacity and human-centered transformation outcomes.

IDV strengthens readiness-outcome relationships through autonomous decision-making and individual exploration of technological benefits. Individualistic societies exhibit proactive engagement with digital services based on personal utility assessments, producing a multiplicative effect where advanced infrastructure combined with a culture of autonomy yields higher levels of human-centered adoption. Examinations of digital transformation initiatives confirm stronger direct relationships between readiness indicators and adoption outcomes within individualistic cultures, contrasting with complex mediation through social influence processes in collectivist contexts [66].

PDI imposes structural barriers limiting information flow and citizen participation, conditioning the relationship between technological readiness and societal outcomes. High PDI contexts concentrate technological capabilities among authority figures or require extensive top-down approval processes, limiting widespread citizen utilization [67, 68]. Since Society 5.0 emphasizes inclusive, citizen-facing governance, such centralized dynamics weaken the translation of readiness into trust, inclusion, and accountability.

H7. *A higher level of long-term orientation strengthens the positive relationship between national technological and AI readiness and the human-centered outcomes of digital transformation.*

LTO reflects societal emphasis on future rewards, persistence, and long-horizon investment [69, 70]. In future-oriented societies (e.g., South Korea, Japan, Germany, Estonia), this orientation supports policy continuity and human capital development, creating conditions conducive to the gradual integration of emerging technologies. By increasing public acceptance of reforms with delayed benefits, LTO acts as a contextual factor that enhances the effectiveness of technological readiness. Accordingly, higher levels of LTO are expected to strengthen the positive relationship between national technological and AI readiness and human-centered digital transformation outcomes.

2-3- Economic and Legal Determinants of the Human-Centered Transition to Society 5.0

The economic perspective prioritizes sustainable scaling capacity, distinct from short-term efficiency metrics. Capacity encompasses human capital investment; enabling infrastructure; coordination among government, business, and science-education sectors; alongside incentives for inclusive digital integration and resolution of long-term societal challenges. Such determinants function as boundary conditions, shaping the conversion of technological readiness into resilient, human-centered outcomes by establishing essential resource bases and investment climates for systemic transformation.

Technology institutionalization into social standards proceeds without automaticity. Sustained adoption hinges on compatibility with formal rules, enforcement predictability, regulatory quality, transparency, accountability, rights protection, and functional mechanisms for redress. These factors condition the perception of digital and AI systems as instruments of public good, separate from sources of asymmetric control. Legal environments thus facilitate realization of technological readiness through inclusive, equitable, and socially trusted governance forms.

H8. *The highest levels of human-centered digital transformation outcomes are achieved in countries where national technological and AI readiness, the overall quality of economic-legal institutions, and a culturally supportive configuration of values combine in a synergistic manner.*

Taken together, these eight hypotheses form an integrated conceptual model that moves beyond isolated main effects to examine how technological readiness, institutional quality, and cultural values jointly shape human-centered outcomes of digital transformation.

Within the Technologies–Institutions–Cultural Values (TIC) model, this relationship can be expressed as

$$HCO = f(T \times I \times CV, Controls) \tag{1}$$

where, T represents technological and AI readiness, I denotes institutional quality and enforceable safeguards, and CV captures the cultural value context that shapes the social legitimacy and acceptance of governed digital transformation.

This formulation explicitly avoids technological determinism and accounts for the cultural contingency of digital transformation trajectories by treating diverse configurations of conditions as determinants of the conversion from capacity into human-centered outcomes.

This conceptual specification is visually summarized in the research model presented below. Figure 2 illustrates the proposed theoretical model, depicting both direct effects and the moderating role of cultural dimensions across national contexts.

The model illustrated in Figure 2 posits that while technological, institutional, and cultural pillars each make a distinct contribution to human-centered transformation, their greatest impact emerges through coherent and synergistic interaction. In this framework, technologies provide the functional capacity for adaptation, institutions guide deployment towards normative goals such as equity, sustainability, and legal certainty, and cultural values shape the public trust and societal resilience required for systemic change. The model identifies three levels of influence explaining why technological diffusion alone is insufficient. First, direct effects indicate that technological readiness and institutional quality independently contribute to human-centered outcomes. Second, moderating effects show that institutional and cultural contexts can either amplify or constrain the conversion of technological potential into social value. Third, the integrated synergy effect represents the highest level of Society 5.0 performance, emerging when advanced technological capacity, mature institutions, and supportive cultural values coexist and mutually reinforce one another. Without this alignment, isolated technological advancement may exacerbate inequalities or limit the practical realization of digital transformation agendas.

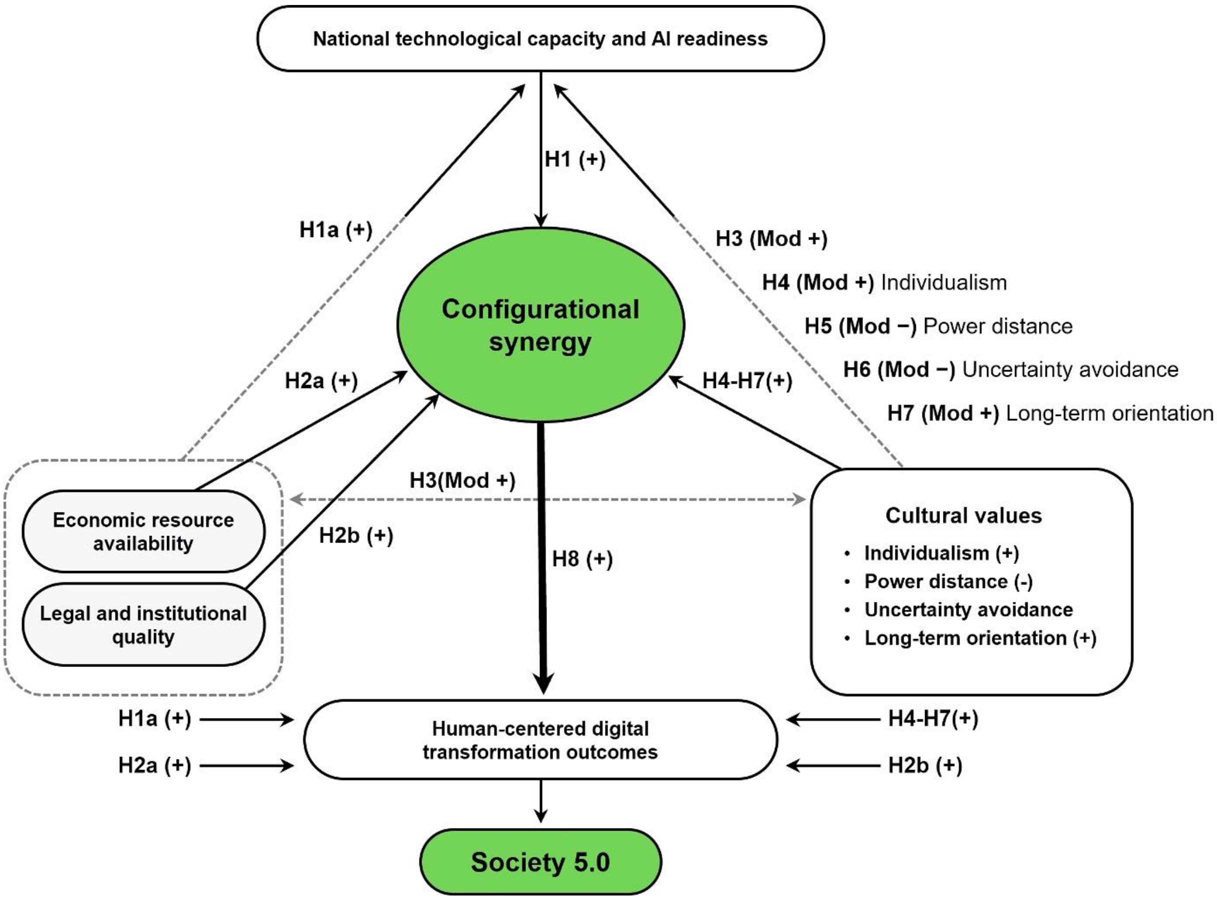

Figure 2. **Research model of the transition towards Society 5.0**

2-4- An Indicator-Based Approach to Assessing Society 5.0

The absence of a universally accepted composite index for Society 5.0, comparable to GDP or HDI, requires a multidimensional indicator-based approach. Such indices function as technologies of governance [71], offering benchmarking and performance-management tools for strategic planning. Although numerous international indices assess digital deployment [72], a Society 5.0 framework requires an integrated measurement strategy that avoids oversimplified aggregation and identifies specific bottlenecks between technological potential, institutional capacity, and societal trust.

The operationalization of this approach follows four principles. First, theoretical validity requires each indicator to correspond to a specific mechanism: for example, the rule of law reflects digital transaction security, while participation metrics capture governance legitimacy. Second, comparability and temporal synchronization require variables to be measured at common time points or incorporated through lag structures to reduce the risk of reverse causality. Third, conceptual overlap is addressed through multicollinearity diagnostics, preventing the artificial inflation of effects caused by correlated composite indices. Finally, methodological transparency is ensured through systematic data normalization and robustness checks using alternative model specifications.

The theoretical foundations and the specific quantitative indicators employed in this assessment are detailed in Tables C2 and C3, respectively (see Appendix C).

The analysis is guided by five research questions that reflect the study's core argument.

RQ1. To what extent is national technological and AI readiness associated with human-centered digital transformation outcomes?

RQ2. Do favorable economic conditions strengthen countries' capacity to finance and sustain socially oriented digital transformation?

RQ3. Is higher legal and institutional quality associated with stronger human-centered outcomes in the transition towards Society 5.0?

RQ4. Does institutional quality moderate the relationship between technological and AI readiness and human-centered outcomes, thereby strengthening the conversion of technological capacity into societal value?

RQ5. To what extent do cultural values moderate the relationship between technological and AI readiness and human-centered outcomes, and how do they help explain cross-country variation in proximity to Society 5.0?

To address these research questions, the study adopts an interaction-oriented empirical strategy to capture the synergistic relationships among the key determinants.

3- Methodology

3-1- Research Design and Data

This study employs a hypothesis-driven, cross-country comparative research design to examine how technological and AI readiness, institutional quality, and cultural values jointly shape digital transformation towards Society 5.0. With countries as the unit of analysis, the empirical strategy moves beyond independent associations by testing the moderating roles of institutions and culture, as well as higher-order interactions among the three pillars. This approach evaluates whether stronger HCO emerge from the synergistic alignment of technological, institutional, and cultural conditions. To reduce interpretive ambiguity within this primarily cross-sectional framework, the study applies a temporal sequencing principle. Cultural dimensions are treated as relatively stable macro-contextual characteristics, whereas technological and institutional predictors are measured before or contemporaneously with the outcome window. The HCO measure is centered on the 2023 reporting period, which represents the most recent internationally comparable data available at the time of analysis. Consequently, the results are interpreted as theoretically structured associations rather than definitive causal effects. To add interpretive depth, the statistical analysis is complemented by expert interviews with specialists from Russia, Brazil, Spain, and Uzbekistan. These interviews provide a qualitative layer for explaining country-specific transition pathways and institutional constraints that are not fully captured by quantitative indicators alone.

3-2- Sample, Selection Criteria, and Data Harmonization

The analytical sample consists of a cross-sectional dataset covering selected countries, constructed using complete-case analysis and including only those countries for which data for all variables were available for 2023. The resulting harmonized sample comprises 102 countries. The sample composition is determined through listwise deletion. For a subset of countries, additional contextual description is provided to facilitate interpretation of the results. Consistent exclusion criteria are applied across all model specifications.

Countries are excluded from the analysis due to missing data, lack of comparability, or the inability to harmonize variables reliably. This approach ensures transparency in the construction of analytical samples for individual models and avoids implicit assumptions that may arise from data imputation or reconstruction, particularly in the estimation of interaction effects.

Country names across datasets are standardized using ISO codes to ensure accurate merging. The cases of ambiguous or inconsistent labeling were resolved manually.

3-3- Measures and Operationalization

The dataset draws on internationally recognized sources. Particular attention was paid to minimizing scale-driven distortions in cross-country comparisons. All indicators included in the composite measures were transformed to a common direction, standardized prior to aggregation, and combined according to pre-specified rules documented in Appendix A. This strategy reduces the risk that the results reflect differences in raw indicator scales rather than substantive variation in the underlying constructs. Robustness analyses evaluate alternative component sets and weighting schemes to verify that the findings are not driven by a single operational choice. Sensitivity tests further address the potential conceptual overlap between technological readiness and institutional governance through alternative operationalizations.

National technological and AI readiness operationalizes using the Oxford Insights Government AI Readiness Index [73], providing internationally comparable country scores reflecting governmental readiness, technology ecosystem maturity, and data infrastructure preparedness. The index captures national-level capacity relevant to AI-enabled public services and digitally mediated governance, serving as a theoretically grounded proxy for national technological capacity distinct from Society 5.0 readiness.

Economic conditions (E) construct an operationalized macro-structural capacity to resource, scale, and sustain socially oriented digital transformation through standardized composites of internationally comparable indicators reflecting economic capacity and enabling conditions. Component definitions and aggregation rules appear fully documented for transparency. In line with H2a, construct models as a distinct predictor.

The legal-institutional environment (L) construct operationalizes legal-institutional governability through standardized composites of cross-country governance indicators reflecting legal enforceability, regulatory quality, implementation capacity, accountability, and institutional safeguards. Pre-specified baseline operationalization appears in the main models, with alternatives examined in the robustness checks. "Construct" interprets as legal-institutional governability, distinct from the mere formal existence of digital legislation. In line with H2b, L models as a distinct predictor.

HCO variable constructs as a composite measure intended to reflect Society 5.0 consistent HCO effects, including inclusive development, capability expansion, resilience, and sustainability alignment. The baseline HCO composite includes indicators that meet three criteria: broad international coverage and comparability; conceptual proximity to Society 5.0-related societal outcomes; and transparent methodological documentation by source institutions.

To ensure theoretical coherence and measurement compatibility, the present analysis relies on four dimensions from Hofstede's model as plausible moderators of the relationship between readiness and outcomes under Society 5.0 logic. Selection rests on methodological and operational grounds. Hofstede provides readily accessible country-level scores consistently harmonizable with macro-level indicators of technological readiness, institutional quality, and human-centered outcomes. Data availability through established datasets enhances transparency and reproducibility. Alternative frameworks, including Schwartz and GLOBE, remain conceptually valuable yet less feasible for the present macro-comparative design. All cultural scores are treated as standardized national-level macro-context variables, interpreted strictly at the country-comparative level, excluding any inference regarding individual-level behavior.

For the three-way interaction model associated with H8, a culturally favorable value configuration conceptualizes as a value environment supportive of societal uptake of digital transformation. Theoretically, such configuration reflects relatively higher individualism, lower power distance, lower uncertainty avoidance, and higher LTO. The baseline specification analyses dimensions separately in the moderation models. Configurational specification combines them into a standardized composite cultural profile, provided the index construction procedure remains transparent and the resulting measure undergoes robustness validation.

3-4- Empirical Specification

3-4-1-Baseline Model

To test the direct-association hypotheses (H1, H2a, H2b), the baseline model regresses HCO on technological and AI readiness (T), economic conditions (E), legal-institutional quality (L), and pre-specified controls:

$$HCO_i = \alpha + \beta_1 T_i + \beta_2 E_i + \beta_3 L_i + \gamma' Controls_i + \varepsilon_i \tag{2}$$

This model tests H1 ($\beta_1 > 0$), H2a ($\beta_2 > 0$), and H2b ($\beta_3 > 0$).

3-4-2- Institutional Moderation Model

The institutional moderation model evaluates whether economic-legal institutional quality amplifies the effect of technological readiness on HCO (H3). The estimation uses an aggregated institutional-context variable derived from the economic and legal dimensions:

$$HCO_i = \alpha + \beta_1 T_i + \beta_2 ELI_i + \beta_3 (T_i \times ELI_i) + \gamma' Controls_i + \varepsilon_i \tag{3}$$

where, T_i denotes technological readiness, ELI_i denotes the composite indicator of economic-legal institutional quality, $T_i \times ELI_i$ represents the interaction term, $Controls_i$ is the vector of control variables, and ε_i is the error term.

This model tests H3, which predicts a stronger positive association between technological readiness and HCO in countries with higher institutional quality.

3-4-3- Cultural Moderation Models

Cultural moderation models test H4–H7 through separate interaction specifications for each cultural moderator. The cultural value dimensions are assumed to condition the association between technological readiness and HCO. The general estimation form is specified as follows:

$$HCO_i = \alpha + \beta_1 T_i + \beta_2 V_i + \beta_3 (T_i \times V_i) + \beta_4 E_i + \beta_5 L_i + \gamma' Controls_i + \varepsilon_i \quad (4)$$

where, V_i denotes the cultural value dimension included in a given model.

The interaction terms correspond to the specific hypotheses: T × IDV for H4, T × PDI for H5, T × UAI for H6, and T × LTO for H7. Substantive inference remains focused on the interaction terms, examining whether the marginal association between technological readiness and HCO varies systematically across cultural contexts. Separate specifications are used to reduce potential multicollinearity among cultural variables, while combined specifications are reserved for supplementary robustness checks.

3-4-4- Synergy Model

The synergy model tests H8 using a three-way interaction specification. The model evaluates whether the association between technological readiness and HCO is strengthened when economic-legal institutional quality and culturally favourable value configurations are jointly present. The estimation equation is specified as follows:

$$HCO_i = \alpha + \beta_1 T_i + \beta_2 ELI_i + \beta_3 VConf_i + \beta_4 (T_i \times ELI_i) + \beta_5 (T_i \times VConf_i) + \beta_6 (ELI_i \times VConf_i) + \beta_7 (T_i \times ELI_i \times VConf_i) + \gamma' Controls_i + \varepsilon_i \quad (5)$$

3-4-5- Country Clustering and Profile Analysis

Cross-country heterogeneity is addressed through cluster analysis based on standardized technological, economic, legal, and cultural dimensions, with sensitivity tests excluding human capital outcomes to prevent leakage. The protocol applies z-score transformation, requires complete cases, and determines the optimal cluster count using internal validation metrics (silhouette score, Calinski–Harabasz index) alongside substantive interpretability; stability is verified through repeated initializations and alternative variable sets, while cluster membership serves exclusively for visualization and descriptive comparison, revealing distinct readiness configurations obscured by average regression estimates.

3-5- Statistical Estimation, Diagnostics, and Robustness

Hierarchical multiple regression employs ordinary least squares (OLS) estimation with heteroskedasticity-consistent (HC3) robust standard errors and mean-centered continuous predictors to mitigate variance heterogeneity, facilitate interaction interpretation, and ensure conservative inference. A unified diagnostic protocol evaluates multicollinearity (variance inflation factors), residual behavior (graphical inspection, Breusch–Pagan, and White tests), and influential observations (Cook's distance and leverage statistics), with sensitivity analyses confirming coefficient stability after excluding high-influence cases. Cross-national spatial dependence is assessed via Moran's I and alternative distance-based matrices, while regional dummy variables control for geographic clustering; significant interactions are probed through simple-slope analysis at substantively meaningful moderator values, and model comparison relies on adjusted fit statistics and information criteria (AIC, BIC).

4- Results

4-1- Descriptive Statistics and Cultural Profiles

4-1-1- Sample Characteristics

The empirical dataset integrates measures of technological readiness, institutional quality, and cultural value dimensions, with alternative sources, such as the Network Readiness Index (NRI) and V-Dem, reserved for sensitivity analyses. Following a complete-case strategy to ensure cross-country comparability and avoid additional uncertainty introduced by imputation, the final sample includes 102 countries across a broad spectrum of economic development levels. Table 1 reports the descriptive statistics for the study variables.

Table 1. Descriptive statistics of the study variables

Variable role	Variable	Description / operationalization, year, source	N	Mean	SD	Min / Max
Dependent	HCO	HCO composite index	102	0.00	0.94	-2.14 / 1.82
Independent	T	Government AI Readiness Index, 2023	102	48.24	15.61	18.12 / 84.80
Independent	E	Economic Conditions composite, 2023	102	-0.02	0.89	-1.65 / 2.41
Independent	L	Rule of Law / Institutional Quality, WGI, 2023	102	-0.05	0.98	-1.82 / 1.96
Moderator	LTO	Long-Term Orientation, Hofstede cultural dimension, 2023	102	46.12	22.45	4.00 / 100.0
Moderator	PDI	Power Distance, Hofstede cultural dimension, 2023	102	61.34	20.12	11.00 / 100.0
Moderator	UAI	Uncertainty Avoidance, Hofstede cultural dimension, 2023	102	64.58	21.35	8.00 / 100.0
Moderator	IDV	Individualism, Hofstede cultural dimension, 2023	102	42.18	23.41	6.00 / 91.00
Control	GDP	GDP per capita, log-transformed, 2023	102	9.24	1.15	6.52 / 11.75
Control	POP	Population, log-transformed, 2023	102	16.15	1.48	12.84 / 21.07

Note. HCO, E, and L are composite or standardized indicators and are therefore reported on transformed scales. The Government AI Readiness Index and Hofstede cultural dimensions are reported on their original 0-100-type scales. To facilitate the interpretation of interaction effects and reduce non-essential multicollinearity, all continuous predictors are mean-centered before constructing interaction terms. In robustness checks, fully standardized specifications are estimated to verify that the results are not driven by differences in measurement scale. Hofstede values refer to the latest available country scores used in the dataset.

4-1-2- Regional Distribution

Descriptive regional profiling shows substantial cross-regional variation in HCO and in the broader model configuration. Regions with stronger governance quality and higher technological readiness tend to report higher HCO levels, while regions with weaker institutional enforceability, lower technological readiness, and less supportive cultural conditions tend to cluster at lower HCO levels. These patterns do not indicate a purely technological divide. Instead, they support the study's central argument that the societal return to technological and AI readiness depends on institutional safeguards and value orientations shaping legitimacy, trust, participation, and adaptive uptake. The configurations are interpreted as descriptive patterns of cross-country variation rather than evidence of single-factor causation.

4-1-3- Correlation Analysis

Pearson correlation analysis was conducted to examine preliminary bivariate relationships among variables and to assess potential multicollinearity concerns prior to multivariate estimation (Table 2).

Table 2. Correlation matrix of study variables

Variable	1	2	3	4	5	6	7	8	9	10
1. HCO	1.00									
2. AI Readiness (T)	0.86**	1.00								
3. Economic Conditions (E)	0.73**	0.66**	1.00							
4. Rule of Law (L)	0.89**	0.82**	0.71**	1.00						
5. LTO	0.41**	0.38**	0.28**	0.35**	1.00					
6. PDI	-0.62**	-0.58**	-0.49**	-0.66**	-0.12	1.00				
7. UAI	-0.18	-0.15	-0.12	-0.21*	0.18	0.24*	1.00			
8. IDV	0.68**	0.65**	0.52**	0.72**	0.14	-0.64**	-0.22*	1.00		
9. GDP per capita, log	0.92**	0.84**	0.76**	0.87**	0.39**	-0.59**	-0.14	0.65**	1.00	
10. Population, log	0.08	0.12	0.09	0.02	0.22*	0.15	-0.04	-0.11	0.05	1.00

Note. Entries are Pearson correlation coefficients. * $p < 0.05$; ** $p < 0.01$; two-tailed tests.

HCO is strongly and positively correlated with T readiness (T; $r = 0.86$, $p < 0.01$), rule of law / institutional quality (L; $r = 0.89$, $p < 0.01$), and log GDP per capita ($r = 0.92$, $p < 0.01$). E also shows a substantial positive association with HCO ($r = 0.73$, $p < 0.01$), indicating that economic capacity is related to, but not identical with, institutional and technological readiness.

Among cultural dimensions, IDV is positively associated with HCO and AI readiness, whereas PDI shows negative associations with both. LTO displays a moderate positive association with HCO, while UAI exhibits comparatively weak bivariate relationships. These patterns suggest that cultural variables may operate less through direct additive effects and more through conditional or interaction-based mechanisms. Hofstede cultural scores are interpreted as macro-cultural indicators for cross-country comparison.

4-1-4- Cultural Profiles

Data originate from cross-country dataset Hofstede Cultural Dimensions by Country, containing scores for six dimensions across countries based on Hofstede's national-level model.

Comparison reveals selected countries differ in broader value configurations, distinct from isolated cultural attributes. Switzerland, Germany, and the United States combine comparatively lower power distance with higher individualism; Japan, South Korea, and China stand out for stronger LTO. Russia, Uzbekistan, Turkey, and, to some extent, Brazil display higher power distance scores alongside more complex combinations across uncertainty avoidance and individualism. Within analytical logic, such differences permit the interpretation of cultural values as macro-level boundary conditions facilitating or constraining translation of technological and institutional readiness into socially meaningful outcomes of digital transformation. Hofstede's dimensions function as aggregated national-level indicators used primarily for cross-country comparison, excluding inference about individuals.

Figure 3 provides broad descriptive overview of country-level differences across Hofstede's full cultural profile.

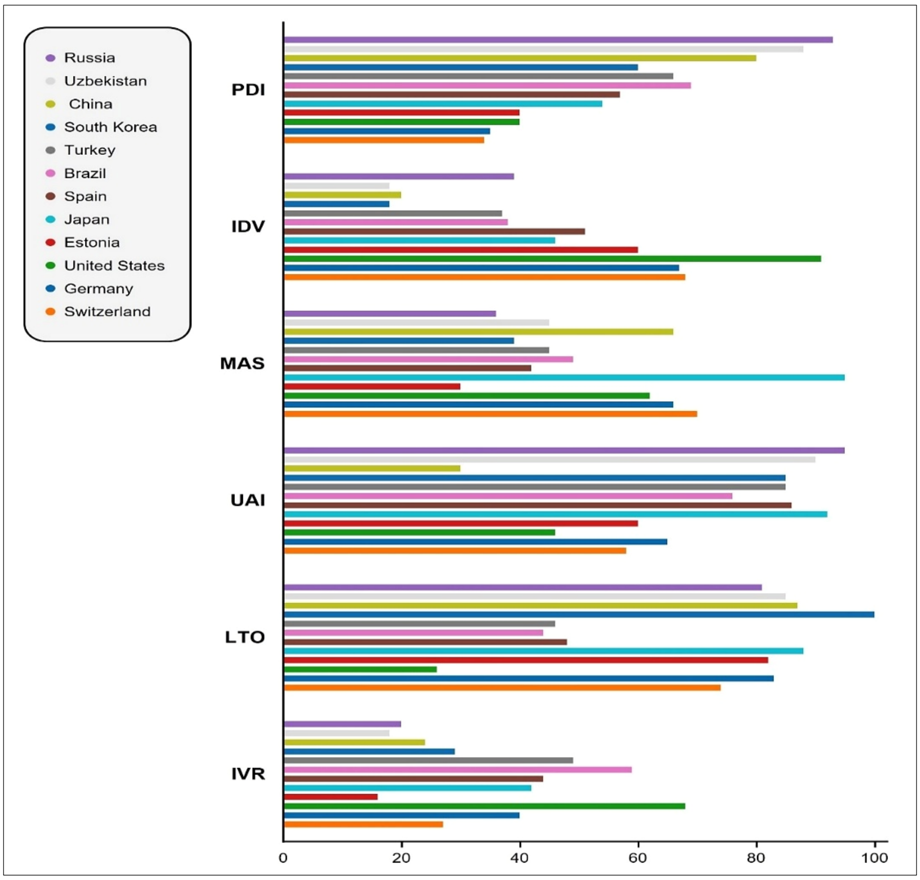

Figure 3. Comparative profiles of Hofstede's six cultural dimensions across selected countries

Figure 4 focuses directly on the four dimensions used in moderation analysis: PDI, IDV, UAI, and LTO [74-76]. Visualization employs a clustered heatmap, combining raw country scores on 0-100 scale with Ward hierarchical clustering based on standardized values. Such approach enables comparison of countries both dimension by dimension and in terms of broader similarity patterns across value configurations.

Figure 4 reveals distinct value configurations across the sampled nations. Germany, Switzerland, the United States, and Estonia combine relatively low power distance with high individualism, reflecting environments associated with lower hierarchy acceptance and stronger emphasis on individual autonomy. Russia, Spain, Brazil, and Turkey exhibit higher power distance and uncertainty avoidance, with Russia standing out for very high scores on both PDI and UAI. China, Japan, and South Korea display comparatively strong LTO alongside moderate-to-high uncertainty avoidance; China differs through combining very high PDI with lower uncertainty avoidance, yet all three share a stronger future-oriented logic.

Dimensional analysis confirms power distance peaks in Russia and China, remaining lowest in Germany and Switzerland. Individualism reaches highest levels in Germany and Switzerland, staying comparatively low in Brazil, Russia, China, and Turkey. Uncertainty avoidance proves strongest in Russia, Japan, Spain, Turkey, and South Korea. LTO remains most pronounced in Japan, South Korea, and China.

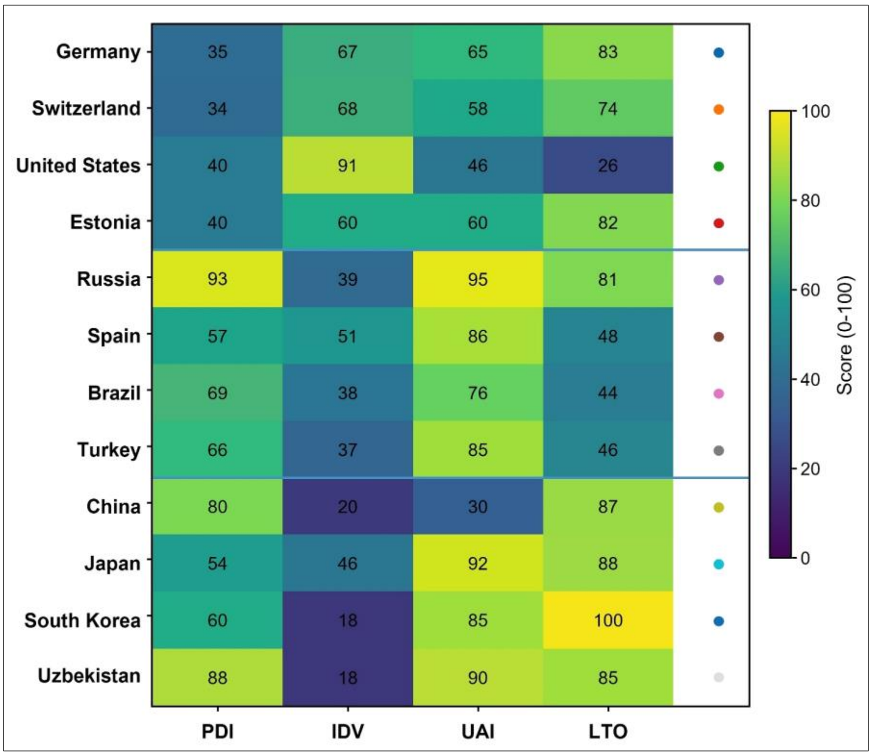

Figure 4. Comparison of Hofstede's cultural dimensions across selected countries (PDI, IDV, UAI and LTO)

Overall, the sampled countries form broader value configurations distinct from isolated dimensional differences. Such configurations function as macro-level contextual proxies shaping national pathways of technological adaptation, institutional response, and translation of digital transformation into human-centered societal outcomes. Interpretation warrants caution: aggregated national-level indicators serve cross-country comparison, excluding inference about individuals given limitations including ecological fallacy, internal heterogeneity, and temporal inertia.

Substantial variation across countries, particularly in PDI and LTO, suggests value context conditions relationships between technological readiness and human-centered outcomes. These configurations provide essential context for interpreting moderation effects.

4-2- Hypotheses Testing

4-2-1- Direct Associations

Table 3 reports direct associations of technological readiness (T), economic conditions (E), and legal-institutional quality (L) with HCO. The baseline specification (Model 1) includes three core explanatory variables. Model 2 adds GDP per capita (log) and population size (log) as macro-level controls. All reported regression coefficients appear as standardized beta coefficients with HC3 robust standard errors and 95% confidence intervals, facilitating the comparison of effect sizes across predictors.

In Table 3, L demonstrates positive and consistent association with HCO across both specifications. Model 1 yields a highly statistically significant coefficient ($\beta = 0.42$, 95% CI [0.26, 0.58], $p < 0.001$). Such association maintains strength following inclusion of macro-level controls in Model 2 ($\beta = 0.31$, 95% CI [0.13, 0.49], $p < 0.001$). Observed pattern aligns with the proposition linking stronger rule-based governance and institutional enforceability to enhanced human-centered outcomes of digital transformation.

Technological readiness (T) demonstrates positive association with HCO across specifications. The baseline model yields a highly significant coefficient ($\beta = 0.28$, 95% CI [0.16, 0.40], $p < 0.001$). Model 2 shows attenuation yet maintains statistical significance ($\beta = 0.14$, 95% CI [0.00, 0.28], $p < 0.05$). Such attenuation indicates a partial overlap between readiness effects and broader development advantages, particularly national income level, yet preserves the independent association between technological readiness and HCO.

Economic conditions (E) coefficient proves positive and statistically significant in Model 1 ($\beta = 0.19$, 95% CI [0.05, 0.33], $p < 0.01$), becoming non-significant in Model 2 ($\beta = 0.11$, 95% CI [−0.05, 0.27], $p > 0.05$) following GDP per capita inclusion. The explanatory role of economic-conditions composite proves sensitive to model specification, potentially overlapping with general development level. Evidence for H2a warrants interpretation as partial, distinct from fully robust.

Table 3. Regression results of the main effects

Variable	Model 1	Model 2
Main effects		
T	0.28*** (0.06) [0.16, 0.40]	0.14* (0.07) [0.00, 0.28]
E	0.19** (0.07) [0.05, 0.33]	0.11 (0.08) [-0.05, 0.27]
L	0.42*** (0.08) [0.26, 0.58]	0.31*** (0.09) [0.13, 0.49]
Control variables		
log GDP per capita	-	0.38*** (0.11) [0.16, 0.60]
log Population	-	-0.04 (0.03) [-0.10, 0.02]
Model diagnostics		
R^2	0.58	0.69
ΔR^2	-	0.11
Adjusted R^2	0.56	0.67
F-statistic	45.11	42.74

Note: All coefficients are standardized betas. Robust standard errors (HC3) are used. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Among the control variables, GDP per capita demonstrates positive and statistically significant association, whereas population size remains non-significant. The increase in explained variance from Model 1 to Model 2 ($\Delta R^2 = 0.11$) indicates macro-development factors contribute meaningful explanatory power beyond the three core predictors. Direct-association models provide support for H1 and H2b, with H2a receiving weaker and model-dependent support.

Explanatory contribution of the model proves not reducible to GDP per capita alone. Income level functions as strong predictor of HCO, yet legal-institutional quality maintains statistical significance following GDP per capita inclusion, and technological readiness retains an independent positive association, albeit with a reduced magnitude. The observed cross-country variation in human-centered outcomes reflects broad development level alongside differences in the capacity to govern, institutionalize, and socially translate technological readiness into meaningful societal outcomes.

4-2-2- Moderation Effects

Table 4 examines the dependence of the AI readiness–HCO relationship on the broader institutional and cultural context. Models test whether ELI quality and selected cultural value dimensions strengthen or weaken the association between technological readiness and human-centered outcomes. All coefficients appear as standardized beta coefficients with HC3 robust standard errors and 95% confidence intervals. Cultural dimensions function as macro-contextual moderators aligned with the Values Survey Module (VSM) design: scores remain comparatively stable, meaningful for cross-country comparison of matched samples, excluding individual-level inference or single-country analysis absent a reference group.

Results reveal variation in AI readiness-HCO relationships across institutional and cultural contexts. Model 3 yields positive, statistically significant T × ELI interaction ($\beta = 0.18$, 95% CI [0.04, 0.32], $p < 0.05$), confirming strengthened association between AI readiness and HCO alongside improved economic-legal institutional conditions. Such pattern confirms H3.

The results for cultural moderation display mixed patterns. Model 4 produces a positive, yet statistically non-significant T × IDV interaction ($\beta = 0.14$, 95% CI [−0.02, 0.30], $p > 0.05$). While this indicates directional alignment with H4, the evidence remains inconclusive for formal empirical confirmation. Model 5 yields a negative, statistically significant T × PDI interaction ($\beta = -0.21$, 95% CI [−0.39, −0.03], $p < 0.05$), thereby supporting H5 and suggesting that hierarchical cultural contexts attenuate the positive association between AI readiness and HCO. Finally, Models 6 and 7 produce negative T × UAI ($\beta = -0.10$, 95% CI [−0.26, 0.06], $p > 0.05$) and positive T × LTO ($\beta = 0.19$, 95% CI [−0.01, 0.39], $p > 0.05$) interactions, respectively. Although directional alignment with H6 and H7 is evident, the statistical evidence remains insufficient for definitive support.

Diagnostic indicators confirm the statistical stability of the moderation models. The inclusion of interaction terms is associated with modest increases in adjusted explained variance (+0.02 to +0.06) relative to the direct-effects baseline.

The most pronounced improvement occurs in Model 5 (PDI), consistent with the substantive relevance of hierarchical cultural contexts in conditioning the relationship between AI readiness and HCO. Multicollinearity diagnostics remain within acceptable limits across all models, with maximum Variance Inflation Factor (VIF) values ranging from 2.85 to 3.40 and mean VIFs from 1.95 to 2.25.

Table 4. Moderation analysis results

Variable	Model 3 (ELI)	Model 4 (IDV)	Model 5 (PDI)	Model 6 (UAI)	Model 7 (LTO)
	Std. β (SE) [95% CI]	*Std. β (SE) [95% CI]*	*Std. β (SE) [95% CI]*	*Std. β (SE) [95% CI]*	*Std. β (SE) [95% CI]*
Main and interaction effects					
T	0.12* (0.06) [0.00, 0.24]	0.16** (0.05) [0.06, 0.26]	0.11 (0.07) [-0.03, 0.25]	0.13* (0.06) [0.01, 0.25]	0.15** (0.05) [0.05, 0.25]
ELI	0.28*** (0.07) [0.14, 0.42]	0.22** (0.08) [0.06, 0.38]	-0.18* (0.08) [-0.34, -0.02]	-0.12 (0.09) [-0.30, 0.06]	0.25*** (0.07) [0.11, 0.39]
T × ELI	0.18* (0.07) [0.04, 0.32]	—	—	—	—
T × IDV	—	0.14 (0.08) [-0.02, 0.30]	—	—	—
T × PDI	—	—	-0.21* (0.09) [-0.39, -0.03]	—	—
T × UAI	—	—	—	-0.10 (0.08) [-0.26, 0.06]	—
T × LTO	—	—	—	—	0.19 (0.10) [-0.01, 0.39]
Additional covariates					
E	(in ELI)	0.08 (0.08) [-0.08, 0.24]	0.10 (0.07) [-0.04, 0.24]	0.12 (0.08) [-0.04, 0.28]	0.09 (0.08) [-0.07, 0.25]
L	(in ELI)	0.28*** (0.09) [0.10, 0.46]	0.25** (0.08) [0.09, 0.41]	0.30*** (0.08) [0.14, 0.46]	0.27*** (0.09) [0.09, 0.45]
log GDP per capita	0.34*** (0.10) [0.14, 0.54]	0.32** (0.11) [0.10, 0.54]	0.36*** (0.10) [0.16, 0.56]	0.38*** (0.11) [0.16, 0.60]	0.35*** (0.11) [0.13, 0.57]
log Pop	-0.03 (0.03) [-0.09, 0.03]	-0.05 (0.04) [-0.13, 0.03]	-0.02 (0.03) [-0.08, 0.04]	-0.04 (0.03) [-0.10, 0.02]	-0.04 (0.04) [-0.12, 0.04]
Model diagnostics					
Adjusted R^2	0.72	0.70	0.73	0.69	0.71
Δ Adjusted R^2 vs. baseline	+0.05	+0.03	+0.06	+0.02	+0.04
F-statistic	36.44	29.11	33.72	27.85	30.56
VIF (max)	2.85	3.15	3.40	3.10	3.22
Mean VIF	1.95	2.10	2.25	2.05	2.15

Note: All coefficients are standardized betas. Robust standard errors (HC3) used. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Overall, the results provide robust empirical support for hypotheses H3 and H5. The testing of H4, H6, and H7 demonstrates directional alignment with the study's theoretical framework. The model elucidates why countries with comparable levels of GDP differ in their capacity to translate technological readiness into HCO, revealing a dependency on institutional quality and, to a lesser extent, cultural values.

4-2-3- Conditional Effects of AI Readiness across Moderators

Conditional effects of AI readiness on HCO were examined across low (−1 SD), mean, and high (+1 SD) levels of institutional and cultural moderators. Such analysis addresses the central theoretical claim: technological readiness produces effects dependent on economic-legal and cultural environments, distinct from uniform impact across all countries.

Table 5 reports conditional effects of AI readiness on HCO at low (−1 SD), mean, and high (+1 SD) levels of each moderator. Results demonstrate systematic conditionality of AI readiness effects. ELI quality displays the clearest amplification pattern. Under weak institutional conditions, the conditional effect of AI readiness remains small and statistically non-significant, suggesting technological capacity alone associates with limited human-centered returns where institutional enforceability, governance quality, and enabling economic conditions prove weak. At the mean ELI level, the slope becomes positive and statistically significant. Under high ELI, the effect increases substantially. Such a pattern supports the proposition that institutions shape the extent to which readiness translates into socially valuable outcomes.

Table 5. Conditional effects of AI readiness on human-centered outcomes

Moderator	Level	Conditional effect	Interpretation
ELI	Low (-1 SD)	0.04 (p > .05)	Weaker institutional context attenuates readiness payoff
	Mean	0.12*	Baseline conditional effect
	High (+1 SD)	0.30***	Stronger institutional context amplifies readiness payoff
IDV	Low (-1 SD)	0.08	Lower autonomy-supportive context weakens readiness payoff
	Mean	0.16**	Baseline conditional effect
	High (+1 SD)	0.24***	Higher individualism strengthens readiness payoff
PDI	Low (-1 SD)	0.28***	Lower hierarchy strengthens readiness conversion
	Mean	0.11	Baseline conditional effect
	High (+1 SD)	-0.06	Higher hierarchy suppresses readiness payoff
UAI	Low (-1 SD)	0.18*	Lower risk aversion enables stronger conversion
	Mean	0.13*	Baseline conditional effect
	High (+1 SD)	0.05	Higher uncertainty avoidance weakens readiness payoff
LTO	Low (-1 SD)	0.03	Shorter-term orientation weakens readiness payoff
	Mean	0.15**	Baseline conditional effect
	High (+1 SD)	0.28***	Long-term orientation strengthens readiness payoff

Note: Conditional effects are derived from the interaction models and are interpreted as simple slopes of AI readiness at low, mean, and high levels of each moderator.

In conclusion, the analysis demonstrates that IDV and LTO foster an environment conducive to the diffusion of AI, whereas hierarchical structures characterized by high power distance significantly impede this process. These findings underscore that institutional quality remains the primary catalyst for digital transformation, while cultural values serve as critical, albeit secondary, factors in achieving the objectives of Society 5.0.

4-3- Synergistic Configuration Effects

To test whether stronger HCO values are associated with the joint alignment of technological readiness, economic-legal institutional quality, and a favorable cultural configuration, a three-way interaction model was estimated. The results are reported in Table 6.

Table 6. Interaction model

Variable	Model 8
T	0.16* (0.07) [0.02, 0.30]
ELI	0.20** (0.07) [0.06, 0.34]
VConf	0.14* (0.06) [0.02, 0.26]
T × ELI	0.11* (0.05) [0.01, 0.21]
T × VConf	0.09 (0.07) [-0.05, 0.23]
ELI × VConf	0.07 (0.08) [-0.09, 0.23]
T × ELI × VConf	0.22* (0.10) [0.02, 0.42]
log GDP per capita	0.28** (0.11) [0.06, 0.50]
log Population	-0.04 (0.04) [-0.12, 0.04]
Adjusted R^2	0.78

Note. *$p < .05$, **$p < .01$, ***$p < .001$

The defining result of Model 8 is the statistically significant three-way interaction (T × ELI × VConf, β = 0.22, $p < 0.05$). This demonstrates that the maximum impact of AI implementation is realized only through the synergy of technological readiness, institutional quality, and cultural values conducive to innovation. While AI readiness (β = 0.16), the institutional environment (β = 0.20), and cultural values (β = 0.14) each possess independent significance, their individual contributions are insufficient to achieve transformative outcomes. Specifically, the significant two-way interaction between technology and institutions (T × ELI, β = 0.11, $p < 0.05$) underscores that economic-legal frameworks are a critical prerequisite for aligning technological advancement with societal well-being.

The model explains 78% of the variance in HCO (Adj. R^2 = 0.78), confirming the high explanatory power and robustness of the proposed TIC framework. Consequently, the analysis proves that technological readiness serves merely as a foundation; genuine social progress towards Society 5.0 emerges only when technology is embedded within high-quality institutions and supportive cultural structures. Optimal outcomes are observed in countries where these three elements evolve in a balanced, synergetic manner, as the 16% direct effect of technology is substantially amplified when aligned with institutional and cultural drivers.

4-4- Robustness Checks

Robustness checks confirm that the primary empirical patterns remain invariant to alternative measurement choices and the exclusion of influential observations. Re-estimating the models with disaggregated HCO components and alternative cultural dimensions (e.g., GLOBE) yielded substantively consistent results, with technological readiness and institutional quality persisting as the most stable correlates of HCO. Further sensitivity analyses, including the exclusion of high-influence cases identified via Cook's distance, failed to alter the direction or significance of the primary coefficients. Although the cross-country design precludes definitive causal identification, the high stability of results across all specifications even after controlling for GDP per capita and population size significantly mitigates concerns regarding omitted-variable bias**.** Collectively, the cumulative evidence provides robust support for H1, H2b, H3, H5, and H8; while H2a receives partial support, hypotheses H4, H6, and H7 remain directionally consistent with the study's conceptual model.

5- Discussion

5-1- Representative Country Profiles

To illustrate the configurational logic of the findings, Table 7 presents representative country profiles across varying levels of HCO. These cases demonstrate how specific combinations of technological readiness, institutional quality, and cultural context translate into divergent societal outcomes.

Table 7. Selected country profiles by human-centered outcomes

Category	Country	T	ELI	CV	HCO
Very High	Finland	77.31	High	Favourable	2.15
	Denmark	73.91	High	Favourable	2.08
	Switzerland	68.57	High	Favourable	1.94
	Norway	72.71	High	Favourable	1.91
	Sweden	72.55	High	Favourable	1.88
	Netherlands	74.47	High	Favourable	1.82
	United States	84.8	High	Favourable	1.35
High	Australia	73.89	High	Favourable	1.3
	Canada	77.07	High	Favourable	1.25
	United Kingdom	78.57	High	Favourable	1.22
	Germany	75.26	High	Favourable	1.18
	Japan	75.08	High	Moderate	1.05
	South Korea	75.65	High	Moderate	0.99
	Spain	67.5	High	Favourable	0.99
	France	76	High	Moderate	0.99
Medium	China	82	Moderate	Moderate	0.55
	Malaysia	69	Moderate	Moderate	0.45
	Russia	71	Moderate	Moderate	0.42
	Kazakhstan	49	Moderate	Moderate	0.18
	Turkey	66	Moderate	Mixed	0.12
	Brazil	65	Moderate	Mixed	0.1
	Thailand	63.03	Moderate	Mixed	0.08
	Vietnam	54.48	Moderate	Mixed	-0.12
	Mexico	50.37	Moderate	Mixed	-0.15
	Uzbekistan	43.79	Moderate	Moderate	-0.22
Low	Indonesia	61.03	Moderate	Mixed	-0.72
	India	62.58	Moderate	Mixed	-0.75
	Morocco	43.34	Low	Mixed	-0.85
	South Africa	47.28	Moderate	Mixed	-0.98
	Egypt	52.69	Low	Mixed	-1.1
	Kenya	40.19	Low	Mixed	-1.15
	Pakistan	42.2	Low	Mixed	-1.22
	Nigeria	39.88	Low	Mixed	-1.35
Very Low	Mali	27.45	Very Low	Unfavourable	-1.62
	Chad	23.44	Very Low	Unfavourable	-1.88
	Yemen	19.89	Very Low	Unfavourable	-2.05
	Afghanistan	21.27	Very Low	Unfavourable	-2.45

Figure 5 presents a country typology derived from Integrated Readiness and Human-Centered Outcomes (HCO). The distribution reveals a pronounced upward trajectory: Benchmark, Advanced, and High-Comfort nations cluster in the upper-right quadrant, demonstrating the strongest alignment between readiness and societal well-being. Conversely, Resource-Dependent and Emerging countries occupy the middle section, while Basic-Survival nations are concentrated in the lower-left quadrant, where low integrated readiness coincides with the weakest HCO performance.

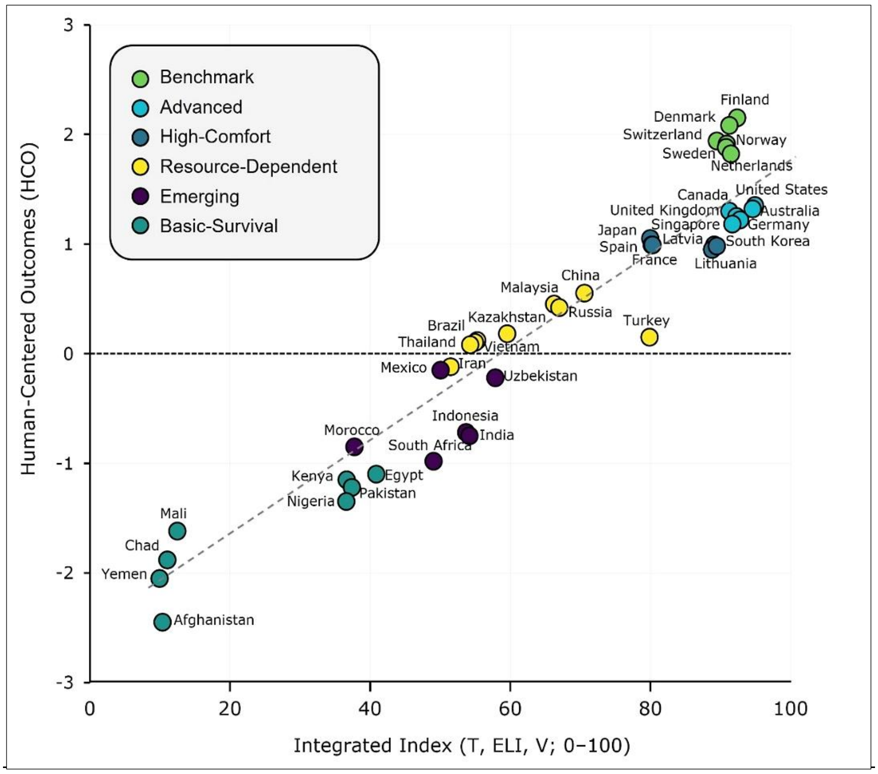

Figure 5. **Country typology based on the integrated readiness index and human-centered outcomes (HCO)**

5-2- Countries that Appear Closest to Society 5.0

Table 8 classifies nations according to proximity to Society 5.0. Classification functions as integrative interpretation of regression findings, conditional-effects analysis, and representative country profiles, distinct from a new causal test.

Table 8. **Representative country positioning and proximity to Society 5.0**

Group under the author's model	Countries	T profile	ELI profile	Cultural profile	Proximity to Society 5.0	Explanation
Benchmark Countries	Finland, Denmark, Switzerland, Norway, Sweden, Netherlands	High	High	Favourable	**Highest**	Synergistic alignment enables effective conversion of readiness into trust-based, inclusive outcomes via robust institutions and participatory culture.
Highly Advanced	United States, Japan, Australia, Canada, United Kingdom, Germany, Estonia, Spain	High	High	Mostly Favourable	**High**	Strong capacity and institutions support high HCO, though internal heterogeneity leads to less balanced social translation than in Benchmark group
High-Comfort Countries	South Korea, France, and Spain	High	High	Moderate/Mixed	**Intermediate-High**	Strong technological/institutional foundations are insufficient for maximal HCO due to moderate cultural alignment or contextual constraints.
Resource-Dependent Countries	China, Malaysia, Russia, Kazakhstan, Turkey, Brazil, Thailand, Vietnam	Moderate to high	Moderate	Mixed	**Intermediate**	Technological momentum is constrained by moderate institutional quality and mixed cultural conditions, limiting full conversion to HCO
Emerging profiles (Conversion-constrained)	India, Indonesia, Mexico, Uzbekistan, South Africa, Morocco	Low/Moderate	Low/Moderate	Mixed	**Distant**	Partial movement towards HCO is structurally constrained by weaker institutional safeguards and less favorable contextual conditions
Basic-Survival Countries	Egypt, Kenya, Pakistan, Nigeria, Mali, Chad, Yemen, Afghanistan	Low	Low/very low	Unfavourable	**Most distant**	Weak readiness, fragile institutions, and unfavorable context jointly limit the possibility of converting digital capacity into social benefit

Note: This table is an integrative interpretation of the regression findings, conditional-effects analysis, and representative country profiles. It is not presented as a separate inferential test. T = Technological Readiness; ELI = Economic-Legal Institutional Quality; HCO = Human-Centered Outcomes).

The taxonomy presented in Table 8 reveals that proximity to Society 5.0 remains fundamentally a function of pillar alignment. Evidence from the benchmark group indicates that high technological readiness generates maximal social value only when supported by robust institutional safeguards and participatory cultural environments. Accordingly, leading nations should prioritize responsible innovation, institutional resilience, and public trust over mere capacity expansion. Conversely, High-Comfort and Resource-Dependent groups illustrate an AI Paradox: high technological capacity fails to guarantee Society 5.0 leadership if institutional governability or cultural uptake remains moderate. In such cases, transition stalls due to conversion bottlenecks where digital assets exist, yet their social utility is dampened by centralized power dynamics or low institutional trust. Ultimately, institutional quality emerges as the most robust predictor, acting as the primary pathway rendering digital transformation socially productive and inclusive.

Income level persists as a strong predictor of HCO, yet economic development alone fails to fully explain cross-national variation in digitally mediated societal performance. Countries with comparable levels of GDP per capita differ substantially in institutional enforceability, regulatory quality, and degree translating technological readiness into inclusion, resilience, trust, and broader public value. Contribution of the present model lies in supplementing income-based explanations with a differentiated account of how technological capacity converts into human-centered outcomes, distinct from replacing such explanations [77].

The application of Hofstede's dimensions captures national cultural tendencies exclusively at a macro-contextual level. Consistent with the Values Survey Module (VSM) design, these indices facilitate robust comparisons across representative country samples; however, they do not account for within-country heterogeneity, individual-level attitudes, or isolated national profiles in the absence of a reference group. Furthermore, dimension scores function as relatively stable indicators that evolve slowly across generations, remaining distinct from the more dynamic fluctuations of contemporary public sentiment.

The present study advances the literature by reconceptualizing Society 5.0 through the integration of three frequently isolated strands [78-80]: technological readiness, institutional quality, and cultural context. Such synthesis shifts the analytical paradigm from viewing digital transformation as a purely technical trajectory to understanding it as a socially embedded process contingent on institutional and cultural alignment. Consequently, the study provides a nuanced framework for explaining cross-national variations in human-centered outcomes, demonstrating that societal value emerges from their synergistic interaction with governance structures and value systems rather than from technological assets alone. This perspective offers a robust alternative to technocentric models by highlighting the critical role of contextual conditions in shaping digital modernization trajectories and determining the ultimate viability of Society 5.0.

5-3- Practical and Policy Implications

The empirical evidence presented herein necessitates a fundamental re-conceptualization of the relationship between technological agency and societal evolution. The transition towards Society 5.0 must be understood as a systemic realignment of the social contract. For corporate actors, the findings demand an exit from the efficiency trap of late-stage technocracy. Future leadership will be defined by socio-technical wisdom, embodying the capacity to architect human-in-the-loop ecosystems where automation serves to augment human dignity and subjective well-being rather than displace them. Corporate strategy must therefore transcend technical KPIs, integrating cultural intelligence and ethical foresight as core competitive assets essential for navigating a volatile geopolitical landscape.

For governments, the implications suggest a shift from passive regulation to proactive institutional stewardship. Innovation policy must move beyond rudimentary sandboxes towards high-fidelity socio-technical environments that stress-test for systemic fairness and social cohesion. State support should be predicated on a verifiable normative convergence, where subsidies are directed exclusively towards innovations that demonstrably reinforce institutional trust. Furthermore, a transformative educational mandate is required to cultivate civilizational literacy. Future leaders must possess the multidisciplinary acumen to govern the complex nexus where algorithmic logic, legal frameworks, and ethical imperatives intersect.

Finally, this study advocates for strategic sequencing in global policy design. Leading nations must champion responsible innovation as a global public good, while developing economies must prioritize the robustification of institutional infrastructure before embarking on large-scale digital transformation. Ultimately, Society 5.0 represents a shift towards sovereign human-centricity. In this new paradigm, digital advancement is the instrument through which states must preserve institutional integrity, ensure cultural continuity, and maintain the delicate equilibrium between rapid innovation and social stability.

6- Conclusions

This study dismantles the techno-deterministic fallacy by proving that AI expansion and digital readiness are not inherent guarantees of a human-centric transition. The study establishes that technological potential is converted into societal well-being solely through the strategic nexus of high-quality institutions, effective regulatory frameworks, and social trust. These elements act as the definitive determinants of whether digitalization serves as a driver of sustainable development or as a catalyst for systemic fragmentation. By integrating global cross-country data with a multi-stage econometric framework, the analysis captures the critical interaction between technological readiness, institutional capacity, and sociocultural moderators.

The results confirm that technological and AI capacity alone fail to generate meaningful societal outcomes; their effectiveness is fundamentally contingent upon the surrounding institutional architecture. These findings challenge linear models by establishing a conditional and co-evolutionary logic of digital transformation. Institutional quality emerges not merely as a supportive factor but as a structural precondition that governs the translation of digital capacity into public value. Simultaneously, cultural configurations function as critical filters, shaping the direction and inclusiveness of this transformation by determining how technology is adopted and socially embedded.

This cross-country analysis reveals a profound divergence in national trajectories, explaining the paradox where digital leaders do not always achieve superior social well-being. Based on these empirical variations, the study proposes an original taxonomy of countries that identifies specific pathways towards Society 5.0. This proves that universal, one-size-fits-all policy models are inadequate; successful transformation requires a precise alignment between digital investments and context-specific institutional landscapes.

Without such alignment, digitalization risks exacerbating inequality and concentrating technological rents. From a normative perspective, Society 5.0 must be redefined as a governance project rather than a technological milestone. The study contributes methodologically by operationalizing human-centered outcomes as a multidimensional construct, providing a roadmap for future research on the causal mechanisms of long-term change. Ultimately, the transition to Society 5.0 is determined by the sovereign capacity of societies to govern, adapt, and humanize that transformation rather than the speed of technological adoption.

Ultimately, this study establishes a fundamental normative-analytical architecture essential for synchronizing technological advancement with the institutional and cultural integrity of society. It transcends conventional analysis by identifying the pivotal mechanisms through which humanity may purposefully humanize the digital frontier, transforming technological evolution into a vehicle for genuine societal flourishing.

6-1- Limitations and Directions for Future Research

While this study establishes a novel transition to Society 5.0, several limitations delineate the boundaries of its interpretation and provide a roadmap for subsequent inquiry.

A primary constraint stems from the reliance on secondary macro-level data, predominantly from the World Development Indicators. Such datasets, while comprehensive for cross-country comparisons, are prone to measurement errors that may restrict the granularity of specific findings. Methodologically, this cross-sectional design identifies theoretically structured associations rather than definitive causalities. Although temporal sequencing was employed to mitigate endogeneity, future research should leverage longitudinal or panel data to capture cumulative effects and the complex feedback loops between technological capacity, institutional quality, and societal outcomes.

The use of macro-proxies, such as composite AI readiness and HCO indices, inherently involves measurement compression. These indicators may not fully encapsulate nuanced dimensions like digital trust, AI fairness, or institutional responsiveness. Subsequent studies could refine this approach by employing latent-variable structural equations or domain-specific indicators that better reflect the normative and ethical imperatives of digital transformation.

The analytical pillars are broad by design. Future research should disaggregate these dimensions to distinguish between state capability, regulatory agility, and bureaucratic adaptability. Furthermore, while Hofstede's cultural dimensions provided a robust baseline, they may overlook subnational heterogeneity and the rapid shift in values triggered by digital acceleration. Testing these moderation effects against alternative frameworks, such as GLOBE or the World Values Survey (WVS), would enhance the robustness of the sociocultural findings.

Despite the inclusion of stringent controls, omitted-variable bias remains a risk. Historical institutional trajectories, geopolitical positioning, and demographic shifts are latent factors that may influence the conversion efficiency of technology into well-being. Future models could integrate quasi-experimental strategies or region-specific controls to strengthen causal identification. Additionally, the complete-case design may limit generalisability, as missing data in institutional reporting is rarely random. Expanded data harmonization is necessary to verify if these patterns remain consistent across diverse income groups and developmental contexts.

Future studies should apply fuzzy-set Qualitative Comparative Analysis (fsQCA) to explore the equifinality of national trajectories, acknowledging that multiple configurational pathways can lead to the same Society 5.0 benchmark.

7- Declarations

7-1- Author Contributions

Conceptualization, R.P., V.P., V.R.S., and M.Va.; methodology, R.P., V.P., V.R.S., M.Va., and M.Vo.; software, V.R.S., N.K., and L.O.; validation, V.R.S., M.Vo., D.E., and O.D.; formal analysis, V.R.S., M.Vo., and E.K.; investigation, V.P., V.R.S., L.O., and E.K.; resources, V.R.S., N.K., and E.K.; data curation, R.P., V.P., V.R.S., D.E., and E.K.; writing—original draft preparation, all authors; writing—review and editing, all authors; visualization, L.O. and O.D.; supervision, R.P., V.P., V.R.S., and M.Va.; project administration, R.P., V.P., V.R.S., and M.Va. All authors have read and agreed to the published version of the manuscript.

7-2- Data Availability Statement

The data supporting the findings of this study are derived from publicly available sources. All raw datasets, along with the processed harmonized dataset and the specific calculations generated by the authors, are available from the corresponding author upon reasonable request.

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7-4- Institutional Review Board Statement

Not applicable.

7-5- Informed Consent Statement

Not applicable.

7-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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Supplementary Material

Appendix A: Construction of Core Indicators and Diagnostic Principles

A1. General Indicator Construction Logic

The empirical design is based on a country-level T–I–CV framework linking technological and AI readiness, economic-legal institutional quality, and cultural value configurations to human-centered outcomes of digital transformation. In contrast to a narrow digital service-access composite, the present specification distinguishes clearly among means, governance conditions, contextual value orientations, and normatively significant outcomes. This distinction is methodologically important because it prevents Society 5.0 from being reduced to digital intensity alone and allows the study to test whether comparable technological capacities translate into divergent societal outcomes under different institutional and cultural conditions.

The indicator architecture therefore follows four analytically distinct blocks. The Technology block captures national technological and AI readiness. The Institutions block captures the economic and legal-institutional conditions under which digital transformation is financed, governed, and safeguarded. The Values block captures macro-cultural context through country-level cultural dimensions. The HCO block captures the main dependent construct, namely, the extent to which digital transformation is associated with human-centered outcomes such as inclusion, well-being, trust-related public value, and socially meaningful developmental performance.

A1.1. Standardization and Harmonization Procedure

Because the underlying indicators originate from different international datasets and are measured on different scales, all non-cultural continuous indicators are harmonized prior to model estimation. To ensure comparability, directionality is first aligned so that higher values consistently indicate more favorable conditions for the relevant construct. Indicators for which lower original values signify better performance are inverted before aggregation or model entry. After directional alignment, variables are standardized across the country sample using z-transformation: $Z_i = (X_i - \mu) / \sigma$, where Z_i denotes the standardized value for country i, X_i is the original observed value, μ is the sample mean, and σ is the sample standard deviation. This transformation places indicators on a common metric, facilitates coefficient comparability, and reduces scale-driven distortions in composite construction and interaction modeling.

When domain-level indices are constructed from more than one standardized component, the resulting domain score is calculated from the aligned z-scores and then retained either in standardized form for regression modeling or, where helpful for descriptive presentation, rescaled to a bounded range for dashboard-style interpretation. Rescaling is used only for communication purposes and does not alter the substantive rank order of countries.

A1.2. Construction of the Technology (T) Block

The Technology block represents national technological and AI readiness. Conceptually, this block captures the country's ability to develop, absorb, and deploy advanced digital and AI-enabled capabilities. Operationally, it is based on internationally comparable indicators reflecting technological capacity, digital infrastructure, innovation capability, and AI-related readiness. In the analytical model, this block functions as the principal 'means' dimension of the transition to Society 5.0. Higher values indicate a stronger structural capacity to implement intelligent, interconnected, and adaptive digital solutions at scale.

Where several technology-related indicators are combined, they are treated as complementary components of a broader readiness construct rather than as redundant measures of the same narrow attribute. Equal weighting is justified when the indicators represent theoretically co-essential dimensions of readiness. Where alternative weighting schemes are considered, these are used for sensitivity analysis rather than as the default specification.

A1.3. Construction of the Institutions (I) Block

The Institutions block captures the quality of the economic and legal-institutional environment within which digital transformation is financed, regulated, and translated into socially meaningful outcomes. In the present study, this block is analytically divided into two related components. The first reflects economic conditions relevant to resourcing, financing, and scaling socially oriented digital transformation. The second reflects legal-institutional governability, including the predictability, enforceability, credibility, and accountability of the rules that shape digital deployment.

For hypothesis testing, these institutional dimensions may be entered either separately or as a broader economic-legal institutional quality measure, depending on the model specification. This approach is consistent with the study's theoretical claim that technological readiness alone is insufficient: digital capacity produces stronger human-centered outcomes when embedded in institutional settings capable of safeguarding rights, coordinating implementation, and maintaining public trust.

The combined institutional index, where used, is constructed from standardized component indicators after directionality checks and conceptual screening for overlap. Aggregation is treated as partial rather than fully substitutive: strong economic capacity is not assumed to compensate fully for weak legal safeguards, and vice versa. This reflects the complementary logic of the T–I–CV model.

A1.4. Construction of the Human-Centered Outcomes (HCO) Block

HCO constitutes the main dependent variable of the study. It is designed to capture the results dimension of Society 5.0, namely, whether digital transformation is associated with outcomes that are normatively meaningful from a human-centered perspective. Rather than measuring digital intensity per se, the HCO block represents the extent to which countries convert digital and AI-related capacities into broader social value.

In operational terms, HCO is derived from country-level indicators reflecting human-centered performance domains such as inclusion, well-being, trust-relevant public value, social equity, and related developmental outcomes, depending on final data availability and conceptual fit. The composite is standardized across the country sample, which is why its mean is approximately zero by construction. Observed minimum and maximum values, therefore, represent countries located at the lower and upper ends of the empirical distribution of human-centered outcomes rather than absolute substantive bounds.

This operationalization is central to the article's methodological contribution because it preserves the distinction between technological readiness as a means and human-centered transformation as an outcome. Accordingly, HCO should not be interpreted as a proxy for digitalization alone, but as an evaluative outcome construct situated downstream from technological and institutional conditions.

A1.5 Construction of the Cultural Values (CV) Block

The Cultural Values block captures macro-cultural context through cross-country cultural indices. In this study, cultural values are treated as aggregated contextual indicators that characterize prevailing value environments at the country level rather than as proxies for individual beliefs or behaviors. The focal dimensions include Individualism (IDV), Power Distance (PDI), Uncertainty Avoidance (UAI), and Long-Term Orientation (LTO), selected because of their theoretical relevance to the social acceptance, legitimacy, and governance translation of digital transformation.

These dimensions are incorporated in two analytically distinct ways. First, they may function as direct contextual correlates of HCO. Second, and more importantly, they are modeled as moderators of the relationship between national technological and AI readiness and human-centered outcomes. In substantive terms, the Cultural Values block specifies the cultural boundary conditions under which technological potential is more or less effectively translated into socially meaningful results.

Consistent with the logic of ecological comparative research, the cultural variables are entered as country-level scores meaningful for cross-national comparison only. They are therefore interpreted as contextual value conditions rather than as direct evidence about individuals.

A2. Operationalization Principles

The indicator-based specification follows several methodological principles. First, theoretical validity requires every indicator be explicitly linked to an underlying mechanism. Technology indicators must correspond to actual readiness or capacity; institutional indicators must correspond to governance, legal certainty, or scaling conditions; and HCO indicators must correspond to normatively meaningful outcomes rather than to digital uptake alone.

Second, comparability and temporal synchronization are essential in cross-country designs. Where possible, variables should be aligned to a common observation year. If complete temporal alignment is not possible, appropriately justified lag structures should be used, especially for institutional predictors, to reduce reverse causality and avoid conflating determinants with outcomes.

Third, conceptual and statistical overlap must be controlled carefully. Many international indices partly reflect broader latent constructs such as development, state capacity, or digital modernization. For this reason, high pairwise correlations, variance inflation factors, and theoretical redundancy are assessed before multiple indicators are entered jointly into the same specification.

Fourth, transparency in data processing is required throughout. All transformations, including standardization, inversion of lower-is-better indicators, treatment of outliers, and handling of missing data, should be documented explicitly. This is especially important in models containing interaction terms, where hidden pre-processing decisions may alter both coefficient magnitude and substantive interpretation.

A3. Reliability, Construct Coherence, and Formative Considerations

Where domain-level indices are formed from several indicators, internal consistency statistics may be reported as supplementary diagnostics. However, the core constructs in the present study should not be interpreted mechanically through a purely reflective measurement lens. Technological readiness, institutional quality, and HCO are better understood as theoretically assembled, partially formative constructs composed of complementary dimensions that need not exhibit very high inter-item correlations.

Accordingly, construct evaluation relies more heavily on content validity, conceptual clarity, and nomological consistency than on reliability coefficients alone. A theoretically coherent composite may remain methodologically appropriate even when its components contribute distinct forms of variance, provided that the indicators jointly represent the construct's intended domain and behave consistently in relation to adjacent variables.

For HCO in particular, the decisive criterion is whether they collectively capture the human-centered results dimension that the T–I–CV framework seeks to explain rather than whether all components are interchangeable manifestations of one latent trait.

A4. Sensitivity and Robustness Procedures

Sensitivity analysis is used to assess whether the substantive findings depend on arbitrary modeling choices. Where composite scores are employed, alternative weighting schemes may be compared with the baseline equal-weighted specification. High concordance across weighting schemes would support the stability of the operationalization and reduce concern that the observed results are artifacts of any single aggregation rule.

Additional robustness checks include re-estimation after excluding potentially influential observations, substituting alternative but conceptually proximate indicators, and testing different lag structures for institutional variables. If the main pattern of findings remains substantively stable across these alternatives, confidence in the analytical specification is strengthened.

Because the study includes interaction terms, robustness checks should also examine whether moderation effects are sensitive to sample composition, variable scaling, and the treatment of outliers. This is particularly important when working with country samples constrained by complete-case requirements.

A5. Diagnostic Protocol for the Empirical Models

The stability and credibility of the empirical estimates are assessed through a structured diagnostic protocol. Multicollinearity is examined using variance inflation factors and correlation diagnostics for all regressors, with particular attention to cultural variables and interaction terms. Functional form and residual behavior are evaluated both graphically and through standard diagnostic tests. Because inference is based on HC3 robust standard errors, strict normality of residuals is not treated as a necessary assumption.

Heteroskedasticity is assessed using conventional procedures such as the Breusch-Pagan and White tests, although HC3 robust standard errors are retained in all specifications regardless of the test outcomes. Potentially influential observations are identified through Cook's distance, leverage statistics, and standardized residuals, followed by sensitivity re-estimation after exclusion of high-influence cases. Statistically significant interactions are probed using simple slopes at substantively meaningful moderator values, and Johnson-Neyman procedures may be used where appropriate. Nested model specifications are compared using adjusted fit statistics and information criteria such as AIC and BIC.

A6. Missing Data and Analytical Sample Definition

The analytical sample is defined at the model level. A country is included in a given specification only if all variables required for that specification are available, comparable, and sufficiently harmonizable. Exclusion criteria are therefore applied symmetrically across model specifications. This procedure preserves transparency in model-specific analytical samples and avoids the implicit assumptions that imputation can introduce into the estimation of interaction effects.

At the same time, complete-case restrictions may introduce a non-random selection effect if countries with missing data differ systematically from those retained in the final sample. For this reason, the findings should not be interpreted as automatically generalizable to all countries worldwide. Future research may address this limitation through broader harmonization efforts, multiple operational datasets, and sensitivity analyses comparing complete-case and expanded-sample specifications.

Appendix B: Overview of National Cultural Dimensions in the T–I–CV Framework

B1. Conceptual Role of Cultural Dimensions

In this study, national cultural dimensions serve as macro-contextual value proxies within the Cultural Values component of the T–I–V framework. Their purpose is to capture cross-national variation in value environments that may influence the legitimacy, social acceptance, and governance translation of digital transformation rather than to explain individual behavior. Countries with similar levels of technological readiness may differ substantially in trust, inclusion, and human-centered digital outcomes because the conversion of capacity into outcomes is filtered through institutional quality and culturally embedded expectations regarding authority, autonomy, risk, and future orientation.

B2. Power Distance (PDI)

Power Distance reflects the extent to which unequal distributions of power are accepted as normal within a society. In the context of human-centered digital transformation, higher PDI may be associated with weaker contestability, lower citizen voice, and more limited bottom-up accountability in data-driven governance. The present study, therefore, treats PDI as a contextual value condition that may be negatively associated with HCO and may also weaken the positive relationship between technological readiness and human-centered outcomes. At the same time, no deterministic interpretation is assumed; the magnitude and sign of the relationship remain empirical questions conditioned by institutional safeguards.

B3. Individualism (IDV)

Individualism captures the extent to which social organization emphasizes autonomy, self-direction, and loosely knit social ties. Within a Society 5.0-oriented framework, higher individualism may be associated with stronger expectations regarding rights, procedural fairness, user-centricity, and accountability. For this reason, IDV is treated as a cultural dimension that may be positively associated with HCO and may strengthen the translation of technological and AI readiness into human-centered outcomes.

B4. Uncertainty Avoidance (UAI)

Uncertainty Avoidance reflects the degree to which members of a society are uncomfortable with ambiguity and unstructured situations. In digital transformation contexts, high UAI may inhibit acceptance when technologies are perceived as opaque, risky, or weakly regulated. Under strong institutional safeguards, however, it may also coincide with greater demand for rule-based governance and compliance mechanisms. In the present study, UAI is treated primarily as a moderator with a theoretically plausible tendency to weaken the T-to-HCO relationship when assurance mechanisms are insufficient, while recognizing that the empirical pattern may depend on institutional quality.

B5. Long-Term Orientation (LTO)

Long-Term Orientation captures the extent to which societies value future-oriented adaptation, perseverance, and long-horizon planning. In the context of Society 5.0, higher LTO is theoretically relevant because sustained digital transformation requires investments whose returns unfold over time and depend on institutional continuity and social patience. Accordingly, LTO is modeled as a cultural condition that may strengthen the positive relationship between technological readiness and human-centered outcomes by supporting adaptive, future-oriented acceptance of socio-technical change.

B6. Interpretation Cautions

Three cautions should be maintained when interpreting country-level cultural scores. First, ecological inference must be avoided: national scores do not describe all individuals within a country and cannot be used to infer personal beliefs or behavior. Second, Hofstede-type measures are historically rooted constructs and may not fully capture within-country heterogeneity across regions, generations, and socio-economic groups. Third, cultural dimensions should not be treated as deterministic explanations of national performance; they are contextual conditions that shape statistical relationships rather than fixed causes of societal outcomes.

Software

Software used for the empirical analysis may include IBM SPSS 29.0 and R 4.3.2 or later for robustness checks, interaction probing, and supplementary diagnostics.

Data Availability

Publicly available datasets were analyzed in this study.

Appendix C:

Table C1. Comparative assessment of national digital transformation models

Country / Region	Policy Initiative / Strategic Framework Name	Conceptual Alignment with Society 5.0	Primary policy driver	Technological Focus	Institutional-governance focus	Human-Centered Outcome Orientation	Flagship Implementation Examples	Key Structural or Institutional Challenges	Data Sources (Official Indicators)	Analytical Cluster	Evidence Confidence Level
Japan	Society 5.0 (Cabinet Office / CSTI)	High	Aging, labour shortages, resilience	AI, IoT, robotics, CPS, data integration	National STI coordination; cross-sector integration	Explicit quality of life, inclusion, resilience	Fujisawa, Kashiwa-no-Ha, Aizuwakamatsu	Uneven territorial implementation; local capacity matters	EGDI; Gov AI Readiness; HDI; SDG-related indicators	A	High
Singapore	Smart Nation / Smart Nation 2.0	High	Urban efficiency, service quality, competitiveness	Sensors, platforms, AI services, digital twin	Strong central coordination (PMO/SNDG/GovTech)	High focus on access, livability, citizen experience	Smart Nation platforms; Virtual Singapore	Privacy and trust balancing	EGDI; Gov AI Readiness; HDI	A	High
EU (supranational)	Industry 5.0 + Digital Decade	Medium-High	Green transition, resilience, competitiveness	Advanced manufacturing, infrastructure, skills, public digital services	Rights-based regulation; monitored targets	Human-centricity, sustainability, inclusion, well-being	Digital Decade targets and monitoring	Uneven member-state capacity	DESI/Digital Decade; EGDI; HDI	B	High
Germany	Platform Industrie 4.0 (EU context)	Medium	Industrial competitiveness, modernization	Automation, interoperability, smart manufacturing	Platform coordination, standards, EU regulation	Skills, worker safety, resilience	Industrie 4.0 platform ecosystem and testbeds	Industrial-efficiency bias risk	EGDI; Gov AI Readiness; HDI; EU metrics	B	High
Spain	España Digital 2026	Medium-High	Competitiveness, social modernization, cohesion	Connectivity, skills, SME digitalization, e-services	National agenda within EU digital framework	Social welfare, access, territorial cohesion	National digital roadmap and implementation	Regional disparities	EU Digital Decade/DESI; EGDI; Gov AI Readiness; HDI	B	High
Sweden	Digitalization Strategy 2025-2030	Medium-High	Competitiveness, resilience, security	AI, digital public services, connectivity	Strong institutional capacity; integrated governance	Welfare-state service capacity and trust governance	National digitalization and AI frameworks	Need to separate cyber priorities from Society 5.0 framing	EGDI; Gov AI Readiness; HDI; EU metrics	B	Medium-High
China	Made in China 2025 + state-led digital strategy	Medium	Industrial upgrading, state capacity, autonomy	Industrial digitalization, smart cities, infrastructure	Strong centralized coordination	Human-centered framing less central than state efficiency	MIC2025 and large-scale rollout	Governance trade-offs; limited equivalence	EGDI; Gov AI Readiness; HDI	C	Medium
UAE	Smart Government / AI strategy	Medium	State modernization, competitiveness, urban management	AI in government, smart-city platforms	Centralized execution; regulatory experimentation	Citizen experience and service efficiency emphasized	Major-city smart governance ecosystems	Inclusion comparability and trade-off assessment	EGDI; Gov AI Readiness; HDI	C	Medium
Russia	Digital Economy of the Russian Federation	Medium	State modernization, infrastructure, autonomy	Digital public services, infrastructure, sectoral digitalization	State-led coordination; partial legal modernization	Human-centered effects mainly via access and efficiency	National program and e-government initiatives	Territorial asymmetry; uneven sectoral depth	EGDI; Gov AI Readiness; HDI	C/E boundary	Medium
Kazakhstan	Digital Kazakhstan, eGov/GovTech	Medium	Public service modernization, inclusion, diversification	eGov, mobile services, digital platforms, emerging AI governance	State-led digital government modernization	Service access, living standards, inclusion (declared aims)	eGov ecosystem; Astana/Almaty smart-city elements	Urban-rural divide; external tech dependence	EGDI; Gov AI Readiness; HDI	D	Medium
Uzbekistan	Digital Uzbekistan 2030	Medium	Modernization, connectivity, competitiveness, inclusion	Digital government, connectivity, platforms, IT ecosystem	State-led transformation and e-gov targets	Improving daily life and service access	Digital government modernization programs	Urban-rural divide; implementation capacity dispersion	EGDI; Gov AI Readiness; HDI	D	Medium
United States	Smart Cities Initiative, city ecosystems	Low-Medium	Mobility, infrastructure, local problem-solving	Smart mobility, civic tech, urban IoT	Federal-local mix; decentralized pilot logic	City-level service improvements and innovation outcomes	USDOT Smart City Challenge and city initiatives	High inter-city variation; weak national coherence	EGDI; Gov AI Readiness; HDI (+ city KPIs)	E	High
South Korea	Smart City / Digital Government ecosystem	Medium-High	Urban innovation, digital government, competitiveness	Smart-city platforms, mobility, data ecosystems	Strong national coordination and digital-state capacity	Service access and urban efficiency	Mature digital government and smart-city ecosystem	Metropolitan concentration; transferability limits	EGDI; Gov AI Readiness; HDI	A/B boundary	High
Estonia	Digital State / e-Government model	Medium-High	State efficiency, interoperability, trustable services	Digital identity, interoperable registries, e-services	Strong legal-institutional architecture	Access, administrative convenience, trust in digital state	Institutionalized interoperable e-governance model	Small-state transferability limits	EGDI; Gov AI Readiness; HDI	B/D boundary	High

Table C2. Theoretical Approaches to the Indicative Assessment of Society 5.0

Approach	Conceptual Focus	Typical Indicator Groups	Advantages and Limitations	Conceptual Foundations	Data Sources / Indices
Technocentric	Society 5.0 is interpreted as an extension of digitalization and AI capacity, with emphasis on technological capacity (infrastructure, data, and innovation base).	AI readiness; connectivity (broadband/mobile); 5G adoption and coverage; data and computing infrastructure (proxy indicators); R&D expenditure; robotics deployment.	(+) High measurability and cross-national comparability; regularly updated. (–) Risk of substituting human-centered outcomes with technological proxies; low sensitivity to safeguards and social legitimacy.		Oxford Insights Government AI Readiness Index; ITU DataHub / World Bank WDI (connectivity/bandwidth); GSMA (5G); UNESCO/OECD/WDI (R&D); WIPO (patents); IFR (robot density).
Economics	Society 5.0 as the economic conversion of digitalization: productivity, scalability of adoption, distribution of benefits, and inclusion.	Digital payments and fintech inclusion; labor productivity and employment structure; ICT and R&D investment; innovation output (proxy indicators).	(+) Links digitalization to economic outcomes and distributional effects. (–) Vulnerable to endogeneity (digitalization ↔ growth); risk of reductionism to GDP growth; requires controls and lagged variables.		World Bank Global Findex; WDI (ICT/R&D etc.); WIPO Global Innovation Index (GII) as innovation proxy; WGI Regulatory Quality (RQ.EST) as a condition of scaling.
Human-centric	Society 5.0 as public value and well-being: quality of life, human development, and inclusion; technologies serve as instruments to achieve societal outcomes.	Well-being and quality of life; accessibility of e-health and e-education services; digital inclusion (digital divide metrics); foundational digital skills (as capacity indicators).	(+) Most aligned with the core philosophy of Society 5.0; outcome-oriented focus. (–) Some metrics rely on subjective or survey-based data; limited cross-national comparability.		UNDP HDI; World Happiness Report (well‑being); SDG Index (SDSN) or official SDG indicators (UN).
Governance & safeguards	Society 5.0 as governability, trust, and legal safeguards: the capacity to convert technological readiness into human-centered outcomes through accountability, rights protection, and enforceable oversight.	Rule of law and enforcement quality; regulatory quality; data protection and digital rights frameworks; cyber resilience; e-participation and e-government maturity; qualitative assessment of regulatory sandboxes and AI ethics governance.	(+) Identifies bottlenecks in the capacity-to-outcome conversion; explains systemic resilience and legitimacy. (–) Institutional quality is difficult to measure; risk of “law in books” bias; requires mixed-methods (quantitative + qualitative) validation.		World Bank WGI (RL.EST, RQ.EST); ITU Global Cybersecurity Index; UN EGDI/E‑Participation; high-quality coding of regulatory modes according to the protocol.
CPS integration	Society 5.0 as cross-sectoral integration of data, services, and smart infrastructure (e.g., smart mobility, smart grids).	Smart city and urban service maturity; Mobility-as-a-Service (MaaS) and integrated mobility solutions; smart grid deployment and energy efficiency; data interoperability and cross-sectoral integration; platform service maturity.	(+) Captures the convergence of digital and physical domains. (–) Data are often available only at city or sectoral level; weak cross-country comparability; demands careful aggregation protocols.		IMD Smart City Index (city level); sectoral international statistics (energy, transport) where comparable time series are available; qualitative assessments of interoperability.
Values, culture & sustainable development	Society 5.0 as social legitimacy and contribution to sustainable development: equity, inclusion, institutional trust, progress toward the Sustainable Development Goals (SDGs); national culture as a moderator of technological returns.	SDG-related outcome indicators; inclusion of vulnerable populations; environmental outcomes (e.g., CO_2 emissions, energy intensity); cultural value orientations (as moderators of technological impact).	(+) Links digital transformation to public value and global agendas (e.g., SDGs); helps explain heterogeneous impacts across contexts. (–) Attribution of outcomes to digital policies is complex; risk of conceptual diffusion; cultural proxies are slow-moving and require cautious interpretation.	Adjacent Industry 5.0 framework; digital transformation framework for interpreting societal effects.	SDSN SDG Index / UN SDG indicators; UNDP HDI; International Environmental Statistics (CO_2 /energy intensity); (optional) Hofstede/WVS with an explicit description of the restrictions.

Table C3. Quantitative and Qualitative Indicators for the Indicative Assessment of Society 5.0

Block	Focus	Quantitative Variables	Qualitative Variables (coded 0-3; diagnostic meaning)	Sources and Methodological Notes
1. Technological and AI capacity	Infrastructure, automation, and innovation base; government readiness to adopt AI and scale digital solutions.	• Government AI Readiness (score, 0-100/0-1 according to the release methodology) • International Internet bandwidth per Internet user (log transformation; winsorizing) • 5G adoption/coverage (or mobile broadband subscriptions as a global alternative) • Robot density (industrial robots per 10,000 employed; if necessary – log) • R&D expenditure (% GDP; GERD; lagged or moving average applied where data gaps occur)	• AI strategy maturity: 0 = no strategy; 1 = declarative policy only; 2 = updated national strategy or action plan; 3 = established implementation mechanisms and monitoring framework. • AI data governance maturity: 0 = absent; 1 = high-level policies; 2 = operational elements (registries, data quality standards, access protocols); 3 = cross-institutional data architecture with enforceable standards and audit mechanisms. • (Optional) Technological sovereignty / supply chain dependency: case-based coding or trade-flow proxies only; excluded from composite index unless robustness checks confirm validity.	Oxford Insights (AI Readiness) [73]; World Bank WDI (bandwidth, connectivity) [81] / ITU DataHub [82]; IFR/Our World in Data (robots) [83]; UNESCO [84] /OECD/WDI (R&D). Normalization and cross-country comparability based on a single reference year; missing data handled via interpolation or exclusion with documentation; preference given to official statistical series.
2. Governability / safeguards	Trust, security, and legal guarantees: the capacity to convert technological readiness into legitimate, accountable digital governance outcomes.	• Rule of Law (WGI RL.EST), recommended lag t-1 • Regulatory Quality (WGI RQ.EST), lag t-1 • ITU Global Cybersecurity Index (GCI) • (Optional) E‑Participation Index / EGDI sub‑components (for robustness)	• Regulatory sandbox maturity: 0 = absent; 1 = isolated pilots or experiments; 2 = formally established frameworks; 3 = scalable, results-oriented sandboxes with documented impact. • AI ethics governance maturity 0 = no ethical principles adopted; 1 = high-level ethical principles declared; 2 = risk assessment and audit mechanisms implemented; 3 = enforceable accountability structures (e.g., appeals, oversight, liability). • Data protection & digital rights maturity (0-3): must be interpreted jointly with Rule of Law indicators (e.g., WGI RL.EST). • Platform work regulation maturity (0-3) reflects the extent of legal protections for workers in digital platform economies (e.g., social security, fair pay, dispute resolution).	World Bank WGI [11] (RL.EST, RQ.EST); ITU GCI [85]; UN DESA (EGDI/E‑ Participation [12]. Institutional variables preferably lagged to address endogeneity; qualitative modules are critical to mitigate the formal rules without effective implementation.
3. Economic outcomes	Economic returns from digitalization and equitable benefit distribution without reduction to GDP growth; proxies for scalability and inclusiveness of economic effects.	• Digital payments (% age 15+) • High‑ technology exports (% of manufactured exports) • Optional GII (overall/outputs) or patents per 1M (as a proxy for the innovation base, not well-being)	• Business‑ model transformation (0-3: from limited or ad hoc digitization to sector-specific platformization or servitization emerging; • Inclusiveness of economic benefits (0-3: availability/coverage of support measures for vulnerable groups and SMEs; digital financial inclusion.	World Bank Global Findex [86]/ G20 FID (digital payments); World Bank WDI (high‑ tech exports) [81]; WIPO Global Innovation Index; WIPO IP Statistics [87]. Methodology: Innovation-related proxies must be clearly distinguished from genuine societal outcomes; models must control for national wealth and economy size to avoid spurious correlations.
4. Human-centeredness and well-being outcomes	Tangible outcomes in quality of life, access, and inclusion; serves as the anchor outcome block for validating Society 5.0 as a public value paradigm.	• HDI • EGDI • Optional Well‑ being • SDG‑ related social outcomes	• Trust in digital government/ADM (0-3 – coded only when based on harmonized international survey instruments) • Disability inclusion module (0-3: barriers/accessibility/universal design) • Time‑ saving/administrative burden (0-3 – coded only when based on a standardized cross-national measurement tool; otherwise treated as case studies)	UNDP (HDI) [88]; UN DESA (EGDI) [12]; World Happiness Report (well‑being) [89]; UN SDG Indicators [85]/ SDSN SDG Index [90]. Methodology: Avoid double-counting (e.g., HDI and SDG indicators often overlap); a pre-specified list of SDG-related proxy indicators must be fixed prior to analysis.
5. Ecosystem Integration and Resilience	Environmental and sustainability outcomes, without unsubstantiated attribution to AI; integration of systems and preparedness for systemic shocks.	• CO_2 intensity (CO_2 /GDP) or CO_2 per capita (inversion: the less=the better) • Energy intensity (inversion) • SDG 7/11/12/13 indicators	• Interoperability and service integration (0-3: from basic frameworks to registries, interdepartmental exchange, and end-to-end services) • Resilience readiness (0-3) – alternatively, a single pre-specified international risk/resilience index may be used	UN SDG Indicators Database [91]/ SDSN SDG Index [90]; International environmental statistics (WDI/IEA/OWID in case of comparability). Indicators such as smart grid deployment, super-app penetration, and recycling rates are typically available only at case or city level; inclusion in cross-country analysis permitted only if harmonized, comparable data series exist.