A Systematic Review of Human Capital in the Digital Economy

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ABSTRACT

The rapid expansion of the digital economy has transformed global production systems, labor markets, trade patterns, and governance structures. In this evolving environment, human capital has emerged as a key determinant of long-term economic competitiveness and resilience. Although studies on digital transformation and workforce development have proliferated, the existing literature remains fragmented across disciplines and geographic contexts. This study aims to conduct a systematic literature review that examines the macroeconomic relationship between human capital and the digital economy. Using the PRISMA framework, 852 records from the Scopus database were screened, yielding 40 studies included in the final synthesis. The analysis identified five dominant research themes: digital-driven economic growth, workforce transformation, digital governance and trade competitiveness, economic resilience, and sectoral digital transformation. The findings consistently demonstrate that digital infrastructure alone is insufficient to generate sustainable economic growth. Instead, outcomes depend heavily on the quality, adaptability, and innovative capacity of human capital. Human capital serves not only as a factor of production but also as a mediator and moderator that shapes the performance of the digital economy by enhancing institutional adaptability, reducing structural constraints, and supporting economic modernization.

Keywords: *Digital Economy, Digital Governance, Economic Growth, Economic Resilience, Human Capital, Workforce Development.*

INTRODUCTION

The global economy is currently undergoing a profound structural transformation driven by digitalization, data-intensive production systems, and rapid technological advancement. This shift reflects a transition from a traditional Information and Communication Technology (ICT) sector toward a comprehensive digital economic architecture that permeates nearly all dimensions of economic activity, including value creation, labor organization, international trade, and governance systems. In this context, digitalization is no longer considered merely a supporting tool but has become the foundational infrastructure of modern economic systems. Consequently, contemporary

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economic discourse increasingly focuses not on whether digitalization matters, but on the conditions under which it generates sustainable growth, competitiveness, and economic resilience (Alijoyo & Meilia, 2025).

Within this transformation, human capital plays a central and strategic role. Classical human capital theory posits that education, skills, and knowledge are key determinants of productivity and income generation (Putra et al., 2025). However, in the digital economy, this concept expands beyond formal education to include digital literacy, advanced cognitive abilities, technological adaptability, innovation capacity, and data management competencies. The emergence of the Fourth Industrial Revolution has intensified skill-biased technological change, increasing the value of high-skilled labor while accelerating the obsolescence of outdated skills (Alijoyo & Meilia, 2025). As a result, economic performance in the digital era increasingly depends on the ability of individuals and societies to absorb, integrate, and strategically apply digital technologies through high-quality human capital.

Empirical evidence supports the complementary relationship between digital capital and human capital. Studies in ASEAN economies indicate that digital economic expansion contributes to resilience only when accompanied by improvements in workforce skills and talent development. This finding is further supported by Alijoyo et al. (2025). Similarly, research shows that restrictive digital regulations may negatively affect trade performance; however, such adverse effects are significantly reduced in economies with strong human capital foundations. This is also reinforced by Alijoyo et al. (2024). At the regional level, digital-oriented policy interventions have been shown to foster structural modernization through innovation enhancement and skilled labor concentration. These findings collectively emphasize that digital infrastructure alone is insufficient to ensure optimal economic outcomes without adequate human capital development.

The COVID-19 pandemic further highlighted this interdependence. The rapid transition toward remote working systems, digital platforms, and data-driven coordination revealed that disparities in digital competencies directly influenced economic continuity and recovery performance. In the post-pandemic context, digital transformation has become a strategic instrument for strengthening economic resilience and workforce readiness (Brynjolfsson et al., 2024). This development reinforces the view that human capital is not only a micro-level educational concern but also a macro-level determinant of systemic economic stability.

Research on human capital in the digital economy remains fragmented, with studies spread across economics, management, education, and public policy, often using inconsistent frameworks and methods. Prior research variously emphasizes digital governance, trade competitiveness, digital human resource transformation, and Environmental, Social, and Governance (ESG) strategies, yet lacks an integrated macro-level framework that captures the interaction between digital infrastructure, institutional quality, and human capital (Abate et al., 2023; Sugiardi et al., 2026). The literature is also geographically concentrated, limiting generalizability, while measurement differences such as education levels, digital literacy, or innovation capacity create further inconsistencies. These issues highlight a conceptual gap regarding how human capital interacts with digitalization, including whether the relationship is linear, non-linear, or threshold-based. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, this study synthesizes existing empirical and theoretical evidence to build a more integrated understanding of the relationship between human capital and digitalization in the digital economy context.

Addressing these gaps, this study aims to conduct a systematic literature review that examines the macroeconomic relationship between human capital and the digital economy. This research offers both theoretical and practical contributions. It consolidates fragmented perspectives on human capital and digital economic transformation into a unified analytical framework. It provides insights for policymakers in designing human capital development strategies that are more aligned with the demands of the digital

economy, thereby enhancing national competitiveness and economic resilience in an era of rapid technological change.

LITERATURE REVIEW

Human Capital Theory in the Digital Context

Human capital theory posits that education, skills, and knowledge are primary determinants of productivity and economic growth, as emphasized by Bosch et al. (2022) and Tan (2022). Traditionally, human capital has been measured through years of schooling or educational attainment. However, in the digital economy, the concept expands to include digital literacy, technological adaptability, innovation capacity, and problem-solving skills aligned with data-driven environments. The Fourth Industrial Revolution has intensified skill-biased technological change, increasing demand for advanced cognitive and technical competencies (Alfonsi et al., 2024; Fu et al., 2025). In this context, human capital no longer functions merely as a labor-enhancing factor but as a strategic asset that determines a country's ability to absorb, adapt, and innovate within digital systems.

Beyond its traditional role, contemporary research conceptualizes digital human capital as a multidimensional construct encompassing not only formal education but also continuous reskilling, technological fluency, digital literacy, and innovation-oriented competencies. Studies by Abate et al. (2023) argue that the absorptive capacity of an economy, its ability to internalize, adapt, and effectively utilize digital technologies, depends on the depth, quality, and adaptability of its human capital base. As digital technologies evolve rapidly, static measures of schooling alone become insufficient proxies for capturing the dynamic and evolving nature of digital capability formation within modern economies.

Human Capital and Digital-Driven Economic Growth

Empirical evidence consistently shows that digital transformation contributes to economic growth when it is supported by strong human capital foundations. Abate et al. (2023) demonstrate that the development of the digital economy significantly strengthens economic resilience in ASEAN countries, particularly when it is accompanied by talent accumulation and favorable demographic structures. In a similar vein, Xiao et al. (2024) find that urban digitalization policies enhance urban economic resilience through the reinforcement of innovation systems and the concentration of skilled labor. These findings indicate that digitalization, in isolation, is insufficient to generate sustained economic growth. Instead, its effectiveness depends on the presence of adequate human capital that can effectively utilize and adapt to digital technologies, thereby amplifying productivity outcomes.

Additional research by Brynjolfsson et al. (2024) emphasizes that digital capital and human capital are complementary rather than substitutive. Economies characterized by high levels of digital infrastructure but low skill intensity tend to experience limited productivity improvements and, in some cases, increased inequality. Conversely, countries that simultaneously invest in digital infrastructure and human capital development are more likely to achieve higher growth multipliers and deeper structural transformation. This complementary relationship highlights the importance of integrating technological advancement with strategic investments in education, skills development, and workforce upgrading to ensure inclusive and sustainable economic development in the digital era.

Digital Governance, Trade, and Institutional Moderation

The effectiveness of digital human capital is strongly influenced by institutional and regulatory environments. Xiao et al. (2024) find that cross-border data regulations can reduce export quality; however, economies with higher levels of human capital are more capable of mitigating these negative effects. This suggests that digital governance frameworks interact with workforce capabilities in shaping trade performance and

broader macroeconomic outcomes. Institutional quality does not operate in isolation but rather plays a moderating role in determining whether digital transformation leads to improved economic competitiveness and productivity gains in the global economy.

In addition, the increasing fragmentation of digital regulations and the rise of digital sovereignty policies have further complicated the relationship between human capital and economic performance (Putra et al., 2025). As digital trade becomes more regulated, new competencies such as regulatory compliance skills, cybersecurity expertise, and data governance knowledge are becoming essential components of national competitiveness. These skills enable economies to adapt to complex digital environments and maintain efficiency in cross-border economic activities. However, despite these developments, much of the existing literature still fails to systematically integrate institutional variables into macroeconomic growth frameworks. This limitation creates an important analytical gap in understanding the full governance–human capital–digital economy nexus, particularly regarding how institutions condition the effectiveness of human capital in driving digital economic transformation.

Work Transformation, Sustainability, and Emerging Dimensions

Beyond macroeconomic growth, recent studies increasingly highlight workforce restructuring and the development of sustainable human capital strategies. Margherita (2022) identifies a rapid transformation in Digital Human Resource Management (DHRM), characterized by growing dependence on analytics-based talent management systems that enhance efficiency and decision-making in workforce planning. In addition, Pasigai et al. (2025) argue that the development of digital human capital should be aligned with Environmental, Social, and Governance (ESG) principles to ensure long-term sustainability and responsible economic development. Sectoral evidence from Tian and He (2025) further indicates that digital specialization can stimulate regional economic revitalization when it is supported by continuous skill accumulation and workforce upgrading. Similarly, post-pandemic restructuring has reinforced the urgency of accelerating digital skill development as a core component of labor market recovery and adaptation.

Moreover, emerging literature emphasizes the growing intersection between digital transformation and sustainability transitions. New forms of competencies, such as green digital skills, circular economic capabilities, and climate-related technological expertise, are becoming increasingly important in shaping future labor market demands (Novirsari & Pranata, 2021). These competencies reflect a broader shift toward integrating environmental sustainability into digital economic development strategies. However, despite this growing recognition, empirical research still rarely examines how digital human capital simultaneously contributes to both economic growth and environmental sustainability outcomes. This limitation highlights the need for more integrative and multidimensional analytical frameworks that explicitly link digitalization processes, workforce transformation, and sustainable development objectives within a unified macroeconomic perspective.

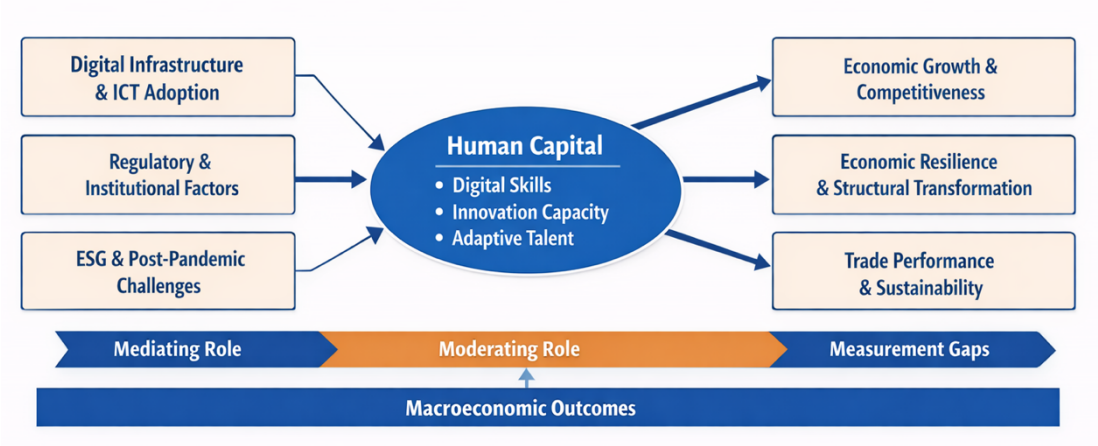

Figure 1. Conceptual Framework

Figure 1 presents a conceptual framework in which digital infrastructure, ICT adoption, regulatory and institutional factors, and ESG-related post-pandemic challenges serve as key drivers that influence macroeconomic outcomes through human capital as the central mediating mechanism. Human capital comprising digital skills, innovation capacity, and adaptive talent acts as the core channel that transforms these inputs into economic growth and competitiveness, economic resilience and structural transformation, as well as trade performance and sustainability, while also functioning as a moderating factor that shapes the strength of these relationships; the model further highlights measurement gaps, indicating that the economic impacts of digital transformation are not always directly observable or uniformly captured.

RESEARCH METHODS

This study adopts a Systematic Literature Review (SLR) approach to synthesize macro-level empirical research examining the relationship between human capital and the digital economy. The review process follows the PRISMA 2020 guidelines to ensure transparency, replicability, and methodological rigor in the identification, screening, and inclusion of studies (Novirsari & Pranata, 2021; Pranata & Sinaga, 2023). The primary data source is the Scopus database, selected due to its comprehensive coverage of high-quality, peer-reviewed international journals in economics, management, public policy, and technology, thereby ensuring consistency in indexing standards and citation reliability (Tan, 2022; Panchal, 2023).

The search strategy employed Boolean keyword combinations reflecting the conceptual intersection between human capital and digital transformation, such as "human capital" AND "digital economy," "ICT" AND "economic development," and "digital governance" AND "human capital." The search was limited to peer-reviewed journal articles published between 2010 and 2026 to capture developments associated with Industry 4.0 and post-pandemic digital transformation dynamics. The initial search yielded 852 records, which were exported in RIS format for further screening and documentation.

The study selection followed the four PRISMA stages. In the identification phase, 852 records were retrieved, of which 284 were duplicates, and 100 were out-of-scope records, leaving 468 studies for screening. During the title and abstract screening phase, 340 studies were excluded for not meeting macro- or meso-level integration criteria between the digital economy and human capital. In the eligibility assessment stage, 128 full-text articles were reviewed, and 88 were excluded due to insufficient macroeconomic relevance, lack of explicit human capital conceptualization, micro-level focus without structural implications, or non-peer-reviewed publication types. Ultimately, 40 studies met all inclusion criteria and were included in the qualitative synthesis, as illustrated in the PRISMA flow diagram in Figure 2.

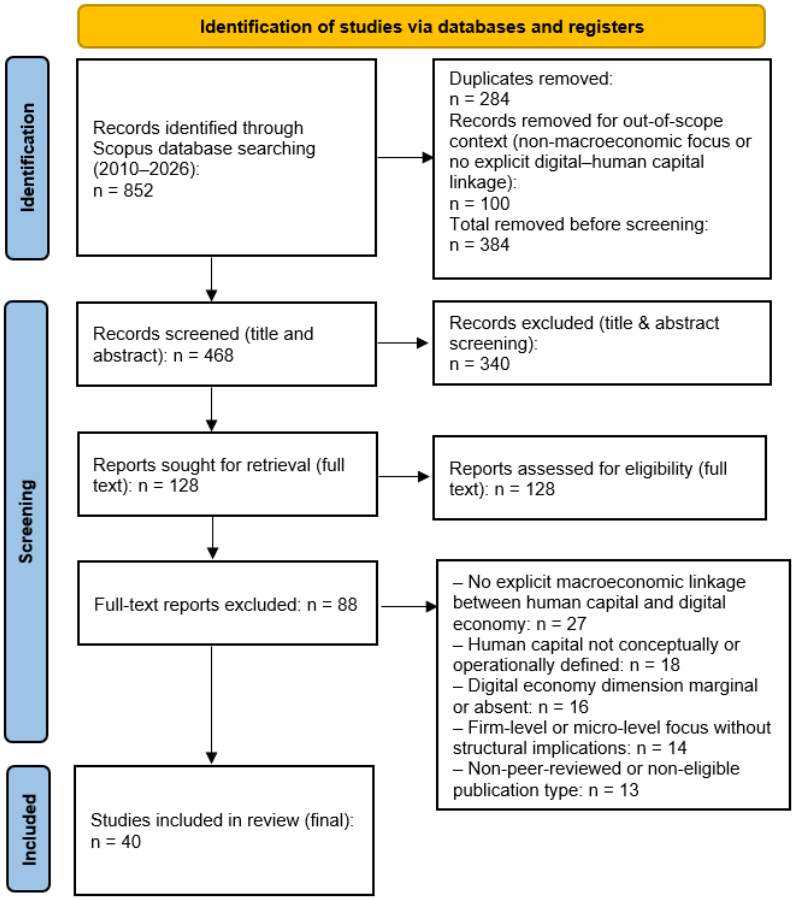

Figure 2. PRISMA Flow Diagram

A structured data extraction protocol was applied to all included studies, capturing key information including authors, publication year, geographic scope, methodological design, operationalization of human capital and digital economy variables, analytical techniques, key findings, and policy implications. The extracted data were subsequently subjected to thematic analysis to identify dominant research clusters. Through iterative coding and comparative analysis across studies, the literature was synthesized into five principal themes, namely human capital and digital-driven economic growth, digital skills and workforce transformation, digital governance and trade competitiveness, human capital and economic resilience, and ESG and digital human capital management. This thematic classification enabled the identification of conceptual convergence, methodological patterns, and structural gaps within macro-level research. Although reliance on a single indexed database may limit the breadth of coverage, the application of a PRISMA-guided systematic procedure ensures analytical transparency and enhances the reliability and rigor of the synthesized findings.

RESULTS

Digital Technologies and Macroeconomic Performance

The synthesis of 40 selected studies demonstrates that digital technologies tend to have generally positive impacts on economic development, although these effects are highly dependent on contextual and structural factors. Empirical evidence from developing countries reveals a consistent pattern in which platform-based digital interventions enhance income stability and employment continuity during the COVID-19 crisis in Bangladesh by Lange et al. (2020) and Wu and Wu (2025), while video-assisted agricultural extension programs in Ethiopia facilitate faster knowledge dissemination and

increase technology adoption among farmers. These findings indicate that digital technologies help reduce information asymmetries, decrease transaction costs, and accelerate the spread of productivity-enhancing practices, particularly in environments with weak institutional support. Accordingly, digitalization can act as an initial driver of economic efficiency improvements in developing contexts.

Nevertheless, the literature consistently argues that digital technologies do not independently generate economic growth. Their macroeconomic outcomes are conditional and strongly influenced by absorptive capacity, which refers to the ability of individuals, firms, and institutions to internalize and utilize external knowledge (Akther & Rahman, 2021; Lousã & Lousã, 2022). In settings where human capital is well developed, digital technologies contribute to higher productivity, greater market access, and improved income stability during economic disruptions. In contrast, where human capital is limited, the benefits of digitalization are often weak or uneven and may even reinforce existing inequalities. This suggests that the relationship between digitalization and economic performance is non-linear and largely dependent on human capital quality.

This interaction is consistent with endogenous growth theory, which emphasizes knowledge accumulation and human capital as key determinants of long-term productivity growth. Digital infrastructure can be viewed as a form of technological capital; however, its productivity depends on the availability of skilled human resources capable of effectively utilizing it (Danish et al., 2018; Makowska-Tłomak et al., 2022; Aguilar et al., 2024). For instance, expanding broadband access without corresponding improvements in digital literacy does not necessarily lead to innovation, while data systems without adequate analytical capabilities fail to enhance competitiveness. In addition, several studies highlight threshold effects, suggesting that significant macroeconomic benefits from digitalization only emerge after reaching a critical level of skills, institutional coordination, and complementary infrastructure (Arthanat, 2019; Aranda et al., 2023). Once this threshold is surpassed, digital diffusion can generate innovation spillovers and structural economic transformation.

Beyond growth effects, the literature also emphasizes the importance of digitalization in strengthening resilience to external shocks. During the COVID-19 pandemic, regions with stronger digital capabilities were more successful in shifting to remote work arrangements, e-commerce, and digital service delivery (Gamliel & Gabay, 2014; Boadu et al., 2018). This suggests that digital human capital serves not only as a productivity-enhancing factor but also as a buffer that stabilizes economies during periods of crisis. However, differences in access to skills, infrastructure, and gender inclusion indicate that digital transformation may widen disparities if not supported by inclusive policy measures (Zúñiga, 2022; El Koshiry et al., 2024). The findings highlight that sustainable digital-driven economic development requires the concurrent strengthening of human capital, institutional readiness, and digital infrastructure.

Human Capital Development through Digital Training

A consistent pattern across the reviewed literature indicates a positive relationship between digital training initiatives and improvements in human capital indicators. ICT training programs have been shown to enhance digital literacy, strengthen self-efficacy in using e-government platforms, and improve cognitive engagement with technology-mediated systems (Lin et al., 2019; Chohan & Hu, 2020). In rural and aging populations, digital literacy interventions not only increase technical proficiency, such as smartphone use, but also contribute to psychological well-being and cognitive stimulation. These findings suggest that digital skill acquisition generates multidimensional benefits that extend beyond narrow economic productivity, encompassing social and cognitive dimensions of human development.

From a theoretical standpoint, these findings support the view that digital skills constitute an advanced form of human capital in knowledge-based economies, characterized by dynamic capabilities such as continuous learning, adaptability, and the integration of digital tools into problem-solving. While digital training can enhance both

technical proficiency and learning agility, empirical evidence suggests that its impact on performance is not always direct, particularly in organizational settings where platform-based training does not consistently improve employee outcomes (Bevilacqua et al., 2021; Zhang et al., 2023). This indicates that the skill–productivity relationship is conditional, depending on broader organizational and institutional contexts rather than occurring automatically.

Several contextual factors mediate the effectiveness of digital training in generating productivity gains, including organizational support, leadership orientation toward innovation, task redesign, and access to enabling technological infrastructure, all of which shape whether training translates into measurable performance improvements (Santini et al., 2023). Moreover, disparities in gender, baseline education, and access to digital resources further influence outcomes, particularly where skill development opportunities are uneven. Without adequate enabling environments, digital training may enhance knowledge without substantially changing work practices. This highlights that digital human capital must be embedded within aligned institutional systems of education, labor markets, infrastructure, and governance. Where such alignment exists, it strengthens innovation capacity and economic resilience; where it does not, training risks becoming symbolic modernization with limited structural impact.

The literature further highlights that the benefits of digital training may be delayed or nonlinear over time. Short-term evaluations often capture immediate improvements in skills, while long-term productivity gains may depend on organizational restructuring and cultural adaptation. This temporal dimension is frequently overlooked in empirical studies, potentially leading to an underestimation of the cumulative and indirect effects of digital training on macroeconomic performance (Lee et al., 2022a; Méndez et al., 2023; Liñares et al., 2025). Moreover, inclusivity remains a critical concern, as poorly designed training programs may unintentionally widen inequality. Individuals with higher initial education levels or better access to digital tools are more likely to benefit, potentially reinforcing skill polarization. Therefore, equitable policy design and differentiated training pathways are essential to ensure that digital human capital development contributes to inclusive growth.

From a macroeconomic standpoint, these findings reinforce the complementarity framework identified in the broader literature. Digital infrastructure expands economic opportunities, but human capital determines the extent to which those opportunities are realized effectively. However, human capital itself is not homogeneous; its productive impact depends on institutional coherence and absorptive capacity (Luthans et al., 2010; Sharma & Rani, 2016; Alex et al., 2022). In the absence of such alignment, digital training resembles the installation of advanced software on outdated hardware, technically functional but operationally constrained. Digital human capital development should be understood as a systemic and adaptive process that requires coordinated investment in skills, institutions, and infrastructure. Without such integration, digital training risks producing fragmented gains rather than sustained structural transformation.

Digital Transformation and Structural Tensions

Digital transformation creates significant opportunities for efficiency gains, innovation acceleration, and market expansion, yet the literature consistently shows that it also generates structural tensions and adjustment costs. A key concept emerging from the reviewed studies is "digital transformation stress," which refers to the misalignment between technological demands and the available cognitive, organizational, and institutional capacities (Ordonez et al., 2011; Sahoo et al., 2025; Xu et al., 2025). When digital systems are introduced without adequate adjustments in skills, workflows, and governance structures, employees often experience overload, uncertainty, and performance pressure. In such cases, rather than improving productivity, rapid digitalization can initially disrupt established routines and temporarily reduce operational efficiency, particularly during early phases of adoption.

This phenomenon is especially evident in knowledge-intensive and highly regulated sectors such as healthcare. Professionals in these fields require continuous and structured training to effectively integrate digital tools into practice and to avoid technological anxiety or skill mismatches (Spataru et al., 2021). These findings reinforce the idea that digital transformation is not merely a technical process but a socio-technical transition that reshapes task allocation, authority structures, accountability systems, and even professional identities. Without coordinated investment in human capital, technological change tends to generate friction rather than synergy. In this sense, the success of digital transformation depends not only on technology deployment but also on the readiness of individuals and institutions to adapt.

The literature further challenges the linear assumption that digital adoption automatically leads to productivity growth. Instead, evidence supports a transitional disruption model in which short-term productivity may stagnate or decline as organizations restructure, employees adjust to new systems, and legacy processes are phased out. These adjustment costs, including retraining expenditures, coordination inefficiencies, and psychological stress, are often underestimated in macroeconomic evaluations of digitalization. At the macro level, such frictions may manifest as temporary productivity slowdowns, labor market polarization, or widening skill-based wage disparities. When technological diffusion outpaces reskilling capacity, high-skilled workers tend to benefit disproportionately, while low-skilled workers face displacement or more precarious employment conditions (Wu et al., 2018; Shah & Adusumalli, 2020; Song et al., 2024).

Beyond labor market effects, structural tensions also emerge from institutional constraints, as regulatory, administrative, and educational systems often lag behind rapid technological change, leading to coordination gaps, governance inefficiencies, and risks such as unclear data governance, cybersecurity issues, and fragmented policy responses. The literature by Montoro et al. (2015) and Avsec et al. (2022) emphasizes this temporal mismatch, where fast technological advancement contrasts with slower human capital formation, creating periods of vulnerability marked by instability and unequal digital gains. However, countries with strong lifelong learning and adaptive training systems are better able to mitigate these challenges, transforming short-term disruptions into long-term productivity improvements. In this context, human capital serves both as an enabler of technological returns and a stabilizing force against institutional instability, reinforcing its central role in sustainable digital economic development (Gamliel & Gabay, 2014; Akther & Rahman, 2021; Bevilacqua et al., 2021).

Innovation Dynamics and the Knowledge Economy

The reviewed studies consistently demonstrate that digitalization functions not only as a mechanism for efficiency enhancement but also as a structural driver of innovation dynamics. Empirical evidence by Alijoyo et al. (2025) indicates that the expansion of the digital economy significantly promotes green innovation and technological upgrading, particularly when supported by conducive institutional environments. Nevertheless, the role of government intervention is characterized by a non-linear, inverted U-shaped relationship. Moderate levels of intervention strengthen innovation ecosystems by reducing uncertainty, enhancing coordination, and facilitating knowledge exchange, whereas excessive regulatory involvement may suppress entrepreneurial incentives and constrain technological experimentation. This pattern underscores that innovation performance in digital economies depends on a delicate balance between market forces and institutional governance.

From a theoretical standpoint, these findings suggest that digital innovation systems operate through a co-evolutionary process involving technological capability, human capital development, and governance quality. Digital technologies reduce information asymmetries, expand collaboration networks, and accelerate knowledge recombination processes. However, the effectiveness of these mechanisms is contingent upon institutional frameworks that encourage risk-taking while simultaneously protecting

intellectual property rights without limiting creative experimentation (Akther & Rahman, 2021). In this regard, innovation emerges not from technological advancement alone, but from the interaction between human capital systems and institutional arrangements that shape the adoption and utilization of digital technologies. This reinforces the view that digital transformation is fundamentally a systemic rather than a purely technological phenomenon.

The literature further highlights a qualitative shift in human capital requirements. Advanced digital competencies, including robotics programming, artificial intelligence modeling, data analytics, and algorithmic design, have become central to the implementation of Industry 4.0 systems (Abate et al., 2023; Tian et al., 2023; Alijoyo et al., 2024). This transition marks a departure from traditional indicators of human capital, such as years of schooling or enrollment rates, toward more specialized and innovation-oriented cognitive capabilities. In contemporary digital economies, competitiveness increasingly depends on the ability to process complex information, integrate technological systems, and generate novel solutions. This evolution reflects the emergence of cognitive-intensity economies, in which value creation is driven primarily by knowledge recombination and digital integration rather than physical capital accumulation.

Importantly, innovation outcomes vary across stages of economic development. In emerging economies, digital platforms often function as leapfrogging mechanisms that enable countries to bypass traditional industrialization trajectories (Bosch et al., 2022; Alfonsi et al., 2024; Wu & Wu, 2025). In contrast, in advanced economies, innovation increasingly relies on frontier research capabilities, interdisciplinary collaboration, and highly developed knowledge ecosystems. Digital human capital assumes different strategic roles depending on structural maturity, facilitating catch-up growth in developing contexts while sustaining frontier innovation in advanced settings. Moreover, digitalization contributes to green innovation through enhanced environmental monitoring, improved energy efficiency, and the development of circular economy systems. However, these outcomes materialize only when technical expertise is combined with sustainability-oriented competencies. The inverted U-shaped effect of government intervention further indicates that effective sustainability transitions require a balance between regulatory coordination and institutional flexibility. Within this framework, digital human capital emerges as a pivotal determinant of whether innovation processes contribute to sustainable economic transformation or remain limited to incremental efficiency gains.

Structural Gaps and Theoretical Fragmentation

Despite substantial empirical advances, the literature on human capital and the digital economy still exhibits structural gaps and conceptual fragmentation. Although many studies confirm positive associations between digitalization and economic outcomes, few provide integrated frameworks explaining how digital governance, institutional quality, and human capital co-evolve to shape macroeconomic trajectories (Alfonsi et al., 2024). Digital governance is often treated as an exogenous background factor rather than an endogenous element of growth processes, despite its influence on investment incentives, innovation ecosystems, and knowledge diffusion (Lee et al., 2022b; Santini et al., 2023; Tian et al., 2023). This omission limits understanding of why similar levels of digital infrastructure produce divergent economic outcomes across countries.

A second limitation concerns temporal scope. Most empirical studies rely on short- to medium-term data, focusing on immediate productivity gains or resilience during shocks, while digital transformation unfolds over much longer time horizons (Sharma & Rani, 2016; Wu et al., 2018). Processes such as intergenerational skill formation, curriculum adaptation, and labor market restructuring require decades rather than years to materialize (Alex et al., 2022; Song et al., 2024). The lack of longitudinal analysis obscures path dependency effects, delayed returns to digital skills, and cumulative inequality

dynamics, potentially overstating short-term benefits while underestimating long-term structural consequences.

Measurement heterogeneity further constrains theoretical and empirical integration. Human capital is operationalized inconsistently across studies, ranging from formal education indicators to digital literacy, innovation outputs, and composite skill indices. Similarly, digital economy indicators vary widely, including ICT penetration, broadband access, and broader digital economy indices (Arthanat, 2019; Bosch et al., 2022). This dispersion weakens comparability and reflects the absence of a unified framework distinguishing between access, usage intensity, innovation capability, and governance quality (Lousã & Lousã, 2022; El Koshiry et al., 2024). Such inconsistencies risk underestimating advanced digital competencies or conflating infrastructure availability with effective utilization.

At a deeper level, the literature remains fragmented across disciplinary boundaries, treating human capital, digital infrastructure, innovation systems, and sustainability transitions as separate analytical domains. This siloed structure limits the development of cohesive macro-level explanations. As digital transformation increasingly intersects with climate transition, demographic shifts, geopolitical data regulation, and inequality dynamics, the absence of integrated frameworks becomes more problematic. Addressing these gaps requires dynamic, multi-level models that capture non-linear effects, institutional mediation, and long-term adjustment processes (Lin et al., 2019; Méndez et al., 2023; Sahoo et al., 2025). The literature clearly demonstrates the importance of digital human capital, it still lacks a comprehensive explanation of how it operates across institutional contexts and time horizons to shape sustainable economic transformation.

DISCUSSION

The synthesis shows that digitalization significantly improves macroeconomic performance, but its impact depends on structural conditions and human capital capacity. In developing countries, digital technologies enhance income stability, expand market access, and accelerate knowledge diffusion, as seen in platform-based interventions in Bangladesh and agricultural extension in Ethiopia, supported by Lange et al. (2020) and Makowska-Tłomak et al. (2022). These findings indicate that digitalization acts as an initial catalyst for economic efficiency, especially in contexts with weak institutions and limited information access. However, its benefits are not automatic and remain highly dependent on the quality of human capital and institutional environments.

Further interpretation suggests that the economic impact of digitalization is conditional rather than automatic. The concept of absorptive capacity is central in explaining cross-country and cross-sectoral variation in outcomes, as it reflects the ability of individuals and institutions to internalize and apply external knowledge effectively (Akther & Rahman, 2021; Lousã & Lousã, 2022). In this regard, digital technologies generate optimal outcomes only when supported by adequate levels of human capital. Conversely, limited skills may weaken the benefits of digitalization or even exacerbate inequality. This indicates a non-linear relationship between digitalization and economic performance, in which human capital quality plays a decisive moderating role.

The findings also reinforce endogenous growth theory, which emphasizes the importance of knowledge accumulation and human capital in driving long-term productivity. Digital infrastructure should not be viewed solely as technological capital, but as a productive input whose effectiveness depends on human capability. This is supported by Danish et al. (2018) and Makowska-Tłomak et al. (2022). Moreover, evidence suggests the existence of threshold effects, whereby significant macroeconomic gains from digitalization emerge only after a critical level of skills, institutional coordination, and complementary infrastructure is achieved. This is further evidenced by Arthanat (2019) and Aranda et al. (2023). This implies that digital investment without parallel human capital development may result in suboptimal or uneven economic outcomes.

Beyond growth effects, digitalization also contributes to economic resilience in the face of external shocks. During the COVID-19 pandemic, regions with stronger digital capabilities demonstrated greater adaptability in implementing remote work and digital service delivery (Gamliel & Gabay, 2014; Boadu et al., 2018). However, these benefits are unevenly distributed due to disparities in skills, infrastructure access, and gender inclusion (Zúñiga, 2022; El Koshiry et al., 2024). Digitalization may simultaneously enhance resilience and widen inequality if not accompanied by inclusive policy frameworks.

At the micro level, human capital development through digital training has been shown to improve digital literacy, self-efficacy, and cognitive capacity, particularly among rural populations and older adults, as highlighted by Lin et al. (2019) and Chohan and Hu (2020). However, these improvements do not always translate into enhanced organizational performance, as they are strongly influenced by institutional factors such as leadership quality, organizational support, and workplace infrastructure, as emphasized by Bevilacqua et al. (2021), Zhang et al. (2023), and Santini et al. (2023). This underscores that digital human capital becomes most effective when embedded within coherent and supportive institutional ecosystems.

Furthermore, digital transformation generates structural tensions characterized by "digital transformation stress," reflecting mismatches between technological advancement and adaptive capacity of individuals and institutions (Ordonez et al., 2011; Sahoo et al., 2025; Xu et al., 2025). These tensions may result in short-term productivity declines, labor market polarization, and wage inequality (Shah & Adusumalli, 2020; Song et al., 2024). At the same time, innovation-related evidence shows that digitalization fosters green innovation and technological upgrading, although its effectiveness depends on balanced government intervention and adequate human capital formation (Tian et al., 2023). These findings emphasize that the macroeconomic impact of digitalization is maximized only when human capital, institutional frameworks, and technological systems evolve in a coordinated and mutually reinforcing manner.

CONCLUSION

This study shows that digitalization has a positive effect on macroeconomic performance; however, its impact is conditional and strongly determined by the quality of human capital and institutional readiness. Digital technologies are found to enhance efficiency, expand market access, accelerate knowledge diffusion, and strengthen economic resilience to shocks. In addition, digitalization fosters innovation, including green innovation, and supports structural transformation toward a knowledge-based economy. Nevertheless, these benefits do not emerge automatically, as disparities in skill access, infrastructure gaps, and differences in adaptive capacity across regions and social groups remain evident. These findings highlight that the relationship between digitalization, human capital, and economic growth is complementary and non-linear, where successful digital transformation depends on the integration of technology, human resources, and institutional quality.

The policy implications of this study indicate that development strategies should not focus solely on expanding digital infrastructure but must also be accompanied by strengthening digital literacy, skills-based education, and adaptive institutional capacity. Without such an integrated approach, digitalization may exacerbate inequality and lead to non-inclusive growth outcomes. However, this study is subject to several limitations, including theoretical fragmentation in the literature, inconsistencies in measurement frameworks, and limited cross-country comparative analysis. Therefore, future research is recommended to develop more standardized metrics, employ longitudinal and spatial analytical approaches, and incorporate sustainability and governance dimensions in order to advance a more comprehensive understanding of digital economic development.

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