

Exploring the Intersection of National Innovation Systems and the Transformative Impact of Digitization

Exploration de l'Intersection entre les Systèmes Nationaux d'Innovation et l'Impact Transformateur de la Numérisation

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Abstract

This article delves into the intricate and dynamic interplay between the national innovation system (NIS) and the transformative influence of digitization, a phenomenon that is fundamentally reshaping economies and societies on a global scale. In the face of this digital revolution, it becomes increasingly imperative to comprehend not only how the traditional structures of NIS can adapt to the demands of digitization but also how they can effectively harness the unprecedented opportunities it presents.

With a comprehensive approach, this article delves into the complexities of integrating digitization into NIS. It critically analyzes the challenges that arise from this fusion, including issues related to workforce skills, regulatory frameworks, ethical considerations, and the digital divide. In addition to its analysis, the article provides valuable policy implications and actionable recommendations. These insights are aimed at policymakers, researchers.

By shedding light on this complex interplay, the article underscores the need for a strategic and forward-thinking approach to aligning NIS with the rapidly evolving landscape of digitization. It emphasizes the importance of cultivating an inclusive and collaborative environment that encourages innovation, fosters digital skills, and leverages technology for sustainable economic development. In conclusion, this article offers a roadmap for harnessing the power of digitization within NIS, shaping a future where innovation thrives amidst the digital revolution.

Keywords : National Innovation System ; Public Policy ; Digitization ; Policymakers ; Technology

Résumé

Cet article explore l'interaction complexe et dynamique entre le système national d'innovation (SNI) et l'influence transformative de la numérisation, un phénomène qui refaçonne fondamentalement les économies et les sociétés à l'échelle mondiale. Face à cette révolution numérique, il devient de plus en plus impératif de comprendre non seulement comment les structures traditionnelles du SNI peuvent s'adapter aux exigences de la numérisation, mais aussi comment elles peuvent exploiter efficacement les opportunités sans précédent qu'elle présente. Avec une approche globale, cet article se penche sur les complexités de l'intégration de la numérisation au sein du SNI. Il analyse de manière critique les défis qui découlent de cette fusion, notamment les questions liées aux compétences de la main-d'œuvre, aux cadres réglementaires, aux considérations éthiques et à la fracture numérique. En plus de son analyse, l'article propose des implications politiques précieuses et des recommandations concrètes. Ces idées sont destinées aux décideurs politiques et aux chercheurs qui explorent les dynamiques complexes de cette transformation.

En mettant en lumière cette interaction complexe, l'article souligne la nécessité d'une approche stratégique et prospectiviste pour aligner le SNI avec le paysage en constante évolution de la numérisation. Il met en avant l'importance de cultiver un environnement inclusif et collaboratif qui encourage l'innovation, favorise les compétences numériques et exploite la technologie pour un développement économique durable. En conclusion, cet article offre une feuille de route pour exploiter le pouvoir de la numérisation au sein du SNI, façonnant un avenir où l'innovation prospère au milieu de la révolution numérique.

Mots clés : Système National d'Innovation ; Politique publique ; Numérisation ; Décideurs Politiques ; Technologie

Introduction

The rapid and relentless advancement of digital technologies is fundamentally reshaping the landscape of industries, commerce, and even the way societies function. As these digital technologies continue to proliferate and evolve, they not only introduce novel possibilities but also disrupt established norms and practices. This transformative process has paved the way for new business models, altered consumer behaviors, and prompted a reconsideration of governance and policy frameworks.

Within this dynamic context, the concept of the national innovation system (NIS) emerges as a central player in shaping a country's capacity to navigate and harness the potential of the digital age. NIS represents a complex and interconnected ecosystem comprising diverse actors such as research institutions, educational bodies, businesses, government agencies, and investors. This intricate web of entities collaborates to foster innovation, which in turn drives economic growth and competitiveness. However, in the face of the sweeping digital revolution, NIS encounters the formidable task of integrating these cutting-edge technologies to enhance its innovative capacity while maintaining its core functions.

Digitization is not merely about incorporating digital tools into existing processes ; it entails a profound reimagining of how innovation is conceived, cultivated, and capitalized upon. The integration of digitization within NIS calls for an exploration of novel paradigms that transcend traditional disciplinary boundaries. The challenge lies in not only adopting digital technologies but also in comprehending their profound implications across sectors.

As industries become more interconnected and data-driven, the role of information and knowledge has gained unprecedented prominence. NIS must now navigate the complexities of data management, analytics, and security to remain effective. Furthermore, the ubiquity of digital technologies blurs the lines between sectors, necessitating collaborative efforts across academia, industry, and government. This demands the creation of new interfaces that enable seamless knowledge exchange and innovative partnerships.

While digitization brings immense promise, it also introduces new vulnerabilities and ethical dilemmas. The rapid pace of technological change can outstrip the formulation of suitable regulatory frameworks. Questions of data ownership, privacy, and cybersecurity have emerged as critical concerns. Therefore, the integration of digitization within NIS is not only a technological challenge but also a socio-political one.

Moreover, as the nature of work transforms and automation becomes more prevalent, NIS faces the task of ensuring a skilled and adaptable workforce. Educational paradigms must adapt to equip individuals with the competencies demanded by a digital economy. This implies a need for collaboration between educational institutions, industries, and policymakers to align education and training with the evolving demands of the job market.

The overarching issue at hand revolves around :

- ❖ How can NIS effectively integrate digitization while maintaining their core functions, in a context where digital technologies rapidly transform industries and societies ? What are the complex challenges related to this integration, the necessary new governance and policy norms, as well as the underlying opportunities to ensure sustainable economic growth and enhanced competitiveness ?

In an attempt to address this issue, our inquiry stems from the general hypothesis that it is possible for NIS which adopt a proactive approach by rethinking their structures, policies, and collaborations to effectively integrate digitization. By emphasizing agile training, adaptable regulations, and innovative cross-sector partnerships, these NIS could address the challenges linked to digitization integration. Consequently, they could not only uphold their essential functions but also seize opportunities to stimulate sustainable economic growth and bolster competitiveness in a rapidly changing landscape.

Within this framework, the present article constitutes an analytical study aiming to shed light on the intricate interplay between the NIS and the transformative impact of digitization.

In the subsequent sections, we delve into the challenges and opportunities (section1) brought forth by the integration of digitization within NIS. We analyze the implications for various stakeholders and sectors (section2), and we offer insights into potential pathways for maximizing the benefits while mitigating the risks (section3). Ultimately, by understanding and harnessing the interplay between NIS and digitization, countries can position themselves at the forefront of the digital revolution, capitalizing on innovation to drive economic progress and societal advancement.

1. Challenges and Opportunities

The integration of digitization into the NIS brings about challenges and opportunities in both the technological and socio-economic realms. This convergence reshapes the innovation landscape and requires a comprehensive understanding of its implications (Liliya, et al., 2020) (Satish, et al., 2019) (Axel, et al., 2019) (Lara, et al., 2019) (Vladimir, et al., 2020).

Digital technologies not only provide new business opportunities but also disrupt existing structures and create vulnerabilities. The emergence of digital technologies, platforms, and infrastructures has transformed innovation and entrepreneurship, impacting value creation and capture. The pervasive digitization of industries and society blurs external boundaries, fuses process and outcome, and shortens innovation cycles. Digital technologies have led to interrelated innovation inputs, compressed innovation processes, and innovation outputs in the form of value-creating platforms. The digital transformation of universities and enterprises requires an adequate government policy and the development of digital competencies and institutions.

1.1 Challenges

1.1.1 Paradigm Shift in Innovation Models :

The traditional linear model of innovation, characterized by sequential stages from research to development to commercialization, is increasingly inadequate in the digital era. Innovation systems need to navigate the shift towards more dynamic and collaborative innovation processes that accommodate rapid iterations and continuous learning. (Harold, et al., 2021) (Roberto, et al., 2021) (Kankam, et al., 2021)

1.1.2 Regulatory Complexity:

Emerging technologies such as artificial intelligence, blockchain, and biotechnology present complex regulatory challenges that require a balanced approach to foster innovation while addressing ethical, legal, and safety concerns (Michiko, et al., 2021) (Michele, et al., 2021) (Erik, et al., 2021) (Cristie, 2021). Governments are facing difficulties in regulating these technologies due to their rapid development and the lack of understanding among legislators (Michele, et al., 2021). Traditional approaches to regulation are becoming obsolete, and new thinking is required to keep up with the fast-paced technological advancements. Regulatory institutions, international standards, and innovative approaches like regulatory co-creation, policy experimentation, and RegTech can help navigate the governance mechanisms and promote responsible development and deployment of these technologies. Striking the right balance between innovation and public protection is crucial, and lawmakers should consider factors such as policy decisions, ethical considerations, transparency, inter-jurisdictional competition, and uniformity when drafting regulations for blockchain and other advanced computational technologies.

1.1.3 Socio-Economic Implications :

The automation potential of digitization poses challenges to labor markets and traditional employment structures. It is crucial for the National Innovation System to address these challenges by preparing the workforce for future jobs and ensuring equitable distribution of skills. This requires preventing disparities in skill availability and distribution, as well as promoting policies that support reskilling and training programs (Melanie, et al., 2019). Additionally, it is important to recognize that technological advancements and digitalization do not necessarily lead to job losses, but rather result in significant restructuring of jobs (Liudmila, 2019). Therefore, policy responses should focus on addressing shifts in skill requirements, promoting organizational change, and addressing the rise of alternative work arrangements (Melanie, et al., 2019). . By implementing appropriate policies at the national, and regional levels, such as education and training policies, active labor market policies, income policies, tax systems, and technology policies, the socio-economic implications of digitization can be effectively managed (Ville-Veikko, et al., 2021).

1.1.4 Digital Divide :

Ensuring equitable access to digital tools, infrastructure, and education is crucial for harnessing the full potential of digitization without exacerbating existing societal disparities (Sophie, et al., 2021) (Thommy, et al., 2021) . The digital divide, which refers to disparities in ICT access, usage, and outcomes, has adverse effects on employment, education, health, social services, and socio-economic development (Richard, 2021) (Moritz, 2021). In addition, the digital divide exacerbates social exclusion (Francesco, et al., 2021). As the global South moves into a digital development paradigm, a new concept called "adverse digital incorporation" is needed to explain the persistence and growth of inequality in this context . Addressing these inequities requires comprehensive data on infrastructure, uptake, affordability, and neighborhood effects . By understanding the factors affecting the digital divide and taking proactive measures, policymakers and organizations can work towards bridging the divide and ensuring digital inclusion for all .

1.1.5 Data Privacy and Security:

The proliferation of digital technologies has led to concerns about data privacy, security breaches, and misuse. Establishing robust data protection mechanisms is crucial for instilling trust among stakeholders and users (Srirang & Kumar, 2022) (Olakunle & Win, 2022) (Jessica, et al., 2021) (NarsingRao, et al., 2022). The COVID-19 pandemic has further highlighted the

need for cybersecurity and data privacy, especially in small businesses with limited IT knowledge and resources (Siriboon & Chalee, 2021). The internet of things (IoT) and smart home technologies have become pervasive, but vulnerabilities in these devices raise concerns about data collection, usage, and access. Efforts are being made to make smart device data more visible and interpretable for consumers. The integration of blockchain technology with e-voting applications presents advantages in transparency and data integrity, but challenges remain in system performance and data privacy. Privacy preservation strategies and privacy legislations, such as the GDPR, are being examined to address privacy-related risks in data analytics.

1.2 Opportunities

1.2.1 Accelerated Innovation :

Digital technologies have the potential to accelerate the innovation cycle by enabling rapid prototyping, testing, and iteration. This can be leveraged by the National Innovation System to bring products and solutions to market faster, thereby enhancing overall competitiveness (Robert & Cooper, 2021) (Rajan, et al., 2021) (Zhou, 2021)

1.2.2 Emergence of New Business Models :

Digitization has led to the emergence of new business models, including subscription-based services, platform economies, and data monetization. These innovative models have been facilitated by the national innovation system, which creates an ecosystem that nurtures and supports them. By embracing digital technologies, companies can unlock new revenue streams and market opportunities. The impact of digitalization on business models has been significant, with digital transformations helping to improve competitiveness and bring competition to a new level (Serhii & Rospopchuk, 2021). The economic costs of data have been reduced, enabling firms to create platform-based ecosystems for value creation and value appropriation (Zoltan, et al., 2021). Advancements in digital technologies have also allowed for the evolution of innovative business models that address changing customer needs and contribute to sustainable development (Nina & Kathrin, 2020). The disruptive ecosystem, fueled by digital technologies, is at the core of this movement, reshaping industries and creating new patterns (Dagfinn, et al., 2020). Business model innovation, driven by digital developments, has become a popular topic, offering companies sustainable competitive advantages and increased returns (Leyla, 2021).

1.2.3 Solving Complex Challenges :

Digital technologies offer unprecedented capabilities for addressing complex societal challenges, from healthcare to climate change. National Innovation System can harness the power of multidisciplinary collaboration and data-driven insights to tackle these issues with innovative digital solutions.

1.2.4 Global Collaboration :

The theoretical literature is positive about the role of digitization (Djoum, 2023) Digitization erases geographical boundaries, facilitating collaboration across countries and regions. National Innovation System can leverage this interconnectedness to engage in cross-border partnerships and knowledge exchange, amplifying innovation potential.

1.2.5 Customization and Personalization :

Digital tools enable the customization and personalization of products and services, enhancing user experiences and satisfaction. National Innovation System can facilitate the integration of these capabilities, fostering user-centric innovation.

In sum, The interplay between the challenges and opportunities encapsulates the essence of the National Innovation System's endeavor to integrate digitization seamlessly. This complex landscape requires proactive strategies that harness the potential benefits while mitigating potential risks. By embracing the opportunities, National Innovation System can evolve into a dynamic ecosystem that not only adapts to the digital age but actively thrives within it. The continuation of this article dissects these dynamics, delving into practical insights that shed light on how National Innovation System can navigate this intricate landscape, poised for sustainable growth and innovation-driven success in the digital era.

2. Policy Implications

This section emphasizes the pivotal role of policy in navigating this convergence. Policymakers must craft regulatory frameworks that foster innovation while safeguarding data privacy, security, and ethics in an evolving digital landscape. Equitable access to the benefits of digitization should be promoted, alongside support for workforce training and re-skilling to mitigate disruptions caused by technological changes.

As the integration of digitization and the national innovation system (NIS) unfolds, policymakers play a central role in shaping the trajectory of this convergence. The dynamic

interplay between technological progress and societal well-being necessitates a strategic and forward-thinking approach to policy formulation.

2.1 Balancing Innovation and Regulation

Creating an environment that encourages innovation while maintaining regulatory oversight is a complex challenge. Policymakers must strike a balance between fostering entrepreneurship and ensuring ethical standards, data privacy, and consumer protection. One approach is the use of regulatory sandboxes, which provide a closed testing environment for firms to experiment with new business models or products with reduced regulatory burden (Christian, et al., 2021). However, it is important to consider the potential risks and costs associated with these advantages, such as market distortion and cronyism (Thomas, 2020). Another approach is the use of nudges as a policy tool, which allows for technological development while relying on the Wisdom of the Crowd to guide regulation in the most efficient direction (Brian & Trace, 2020). Embracing artificial intelligence, considering "soft law" as an option, and promoting corporate citizenship are also recommended policy proposals (Nissim & Hadar, 2020). Overall, policymakers need to develop nuanced regulatory frameworks that balance innovation and regulation to foster entrepreneurship while ensuring ethical standards and consumer protection (Sven-Olof & Lars-Gunnar, 2021).

2.2 Navigating the Digital Landscape : Balancing Data Governance, Ethics, and Agile Regulation

In the rapidly evolving digital landscape, three critical pillars interconnect to shape a holistic approach to technology governance. First, "Data Governance and Privacy" forms the foundation, as policymakers establish robust regulations to manage the influx of data-driven technologies. Guidelines for data collection, storage, sharing, and usage are implemented to safeguard user privacy, mitigate data misuse, and foster trust within digital ecosystems. This leads seamlessly to "Digital Ethics and Accountability," recognizing that as technology becomes integral to daily life, ethical considerations are paramount. Policymakers address challenges tied to algorithmic bias, accountability in AI-driven decisions, and the responsible adoption of emerging technologies. Finally, "Agility in Regulation" emerges as the binding force. The swift pace of technological progress necessitates adaptive regulations that accommodate innovations while upholding societal well-being. By embracing flexible frameworks, policymakers ensure technology's potential is harnessed while aligning with the

greater good. Together, these pillars establish a comprehensive approach to navigating the digital realm, ensuring responsible, ethical, and adaptable governance.

2.3 Promoting Equitable Access

Policymakers should develop strategies to ensure equitable access to digital tools, infrastructure, and information, in order to prevent the exacerbation of existing inequalities (Maurizio, et al., 2021). Digital technologies have the potential to empower citizens and increase participation, but barriers to adoption and accessibility must be addressed through inclusive design methodologies (Ursula & Lise, 2022). Additionally, digitalization can provide opportunities to address societal challenges and contribute to building a sustainable future (Maria, et al. 2021). However, the use of big data and advanced computational methods in decision-making requires best practice digital infrastructure design to ensure sound and ethical use, while avoiding unintended consequences and adverse social policy outcomes (Deepti, 2021). By considering key technical infrastructure considerations throughout the data analysis pipeline, policymakers and researchers can design or upgrade digital infrastructure that allows for the equitable access and use of big data (Robyn, et al., 2021).

2.4 Fostering Digital Progress: A Comprehensive Policy Framework

In the realm where digitization converges with the National Innovation System (NIS), a comprehensive policy landscape takes shape through four interwoven pillars. Policymakers assume a pivotal role in shaping public perception and awareness of the ramifications arising from this synergy, engaging citizens in discussions about benefits, risks, and potential policy pathways. This foundational step creates an informed and participatory digital society. Acknowledging the imperative for adaptable skills in a rapidly evolving technological landscape, investment in education becomes crucial. Policymakers must channel resources into educational systems that equip individuals with competencies suited for the digital age, fostering critical thinking, digital literacy, and technical prowess. Simultaneously, fostering research and innovation ecosystems becomes instrumental in driving progress. Policymakers should incentivize investments in cutting-edge technologies and processes, enabling a forward-leaning environment via research grants, tax incentives, and intellectual property protections. As digitization transcends borders, policymakers are tasked with global collaboration to set harmonized standards, address transnational challenges, and facilitate cross-border innovation initiatives. These interconnected pillars collectively establish a policy paradigm that propels

societies towards effective navigation of the intricate crossroads of NIS and digitization, ensuring a responsible and transformative digital future.

2.5 Collaboration Across Sectors

Policymakers play a crucial role in facilitating collaboration between academia, industry, and government (Nathan, et al., 2018). They can create platforms for knowledge exchange, incentivize partnerships, and promote cross-disciplinary initiatives to maximize the potential of digitization within the National Innovation System (Rong, et al., 2021). Measures such as academician workstations, joint platforms between listed firms and academicians under provincial governments, have been found to significantly increase firms' innovation input, quality, and efficiency (Melissa, et al., 2016). These workstations primarily promote corporate innovation by attracting talented human capital rather than through funding support (Robyn, 2016). Additionally, cross-sector collaborative partnerships (CSCPs) are needed to achieve collective responsibility and address sustainability challenges (Paul & Abdullah, 2016). Policymakers can support these partnerships by encouraging collaboration across sectors and recognizing the important contributions of government, academia, and civil society organizations. By embedding well-established strategic decision-making theories, future research can provide rigor to the field of collaboration and inform policymaking.

3. Practical Applications

This section, situated within the continuum of the existing literature, serves as a critical resource for researchers and practitioners who seek to navigate the complex interplay between the NIS and the transformative impact of digitization. It offers practical insights and actionable recommendations that facilitate informed decision-making and effective strategies within this evolving landscape.

3.1 Holistic Understanding of Dynamics

Researchers gain a comprehensive understanding of the intricate dynamics between the NIS and digitization through case studies, theoretical frameworks, and empirical evidence. They explore how these two domains intersect and influence each other (Duane, et al., 2007) (Gönenç, et al., 2011). By studying the diffusion dynamics of innovation and the role of information diffusion, they uncover the extent to which information imperfections and dynamics can influence the diffusion process (Kenneth, et al., 2010). Additionally, they use simulation models to develop general insights about dynamic processes and demonstrate the

impact of information imperfections and learning processes on diffusion patterns (Loet, 2021). Furthermore, they utilize bibliometric mapping techniques to investigate and represent distinctive perspectives on the innovation process, enabling the reconstruction of facets of innovation dynamics (Loet, et al., 2013). Overall, these studies provide a holistic understanding of the dynamics between the NIS and digitization, shedding light on their interactions and influences.

3.2 Ecosystem Mapping

Researchers can benefit from mapping the NIS ecosystem and its digital components to identify key stakeholders, dependencies, and potential collaboration points. This mapping helps in formulating effective strategies and interventions (Evan, et al., 2022). The concept of entrepreneurial ecosystems has gained significant attention, leading to the need for robust empirical measures that capture the complexity of dynamic relationships among ecosystem constituents (Erkko, et al., 2021). There are three basic types of innovation ecosystems, all focusing on the collective production of a coherent system-level output (Yanzhang, et al., 2021). The intellectual structure of current innovation ecosystem research consists of five streams: technology innovation, platform innovation ecosystem, regional development, innovation ecosystem conceptualization and theorization, and entrepreneurship and innovation (Badziili, et al., 2021). Open-source visualization tools can enhance the understanding of SME ecosystem structures, revealing attributes such as clusters and bridges, tie size, structural holes, role structure, and interactivity (Jan, et al., 2021). A firm's connections within its ecosystem influence its ability to innovate.

3.3 Technology Transfer Strategies

For Technology transfer offices (TTOs) need to adapt their strategies to accommodate the challenges and opportunities posed by digitization (Ciara, et al. 2021). TTOs have taken different responses to environmental stimuli, conducted benchmarking, and engaged in professional development and agenda setting activities (Furqaan, et al., 2021). The use of technology in the healthcare industry can leverage patient empowerment and adherence to treatments, minimizing human error and data loss (Tymchenko, et al., 2020). Creating a specialized organizational structure, such as a TTO, in higher education institutions (HEIs) is important for establishing communication between scientists, business, and the state (James, et al., 2020). TTOs have expanded their roles, activities, and responsibilities to meet increasing internal and external pressures (Daniela, et al., 2021). TTOs play an active role in stimulating

universities' entrepreneurial capabilities through science and technology entrepreneurship education (STEE). Older, strategically autonomous TTOs located in universities with strong relevance to technology transfer activities are particularly active in STEE .

Ultimately, this article provides researchers and practitioners with a valuable roadmap for navigating the convergence of NIS and digitization. By embracing fostering collaboration, and tailoring strategies to the digital era, stakeholders can position themselves at the forefront of innovation, driving sustainable growth and societal advancement in the digital age.

Conclusion

In the dynamic and constantly evolving landscape of innovation and technology, this paper has undertaken an exhaustive exploration of the convergence between national innovation systems (NIS) and the transformative impact of digitization. Through an in-depth analysis of the intricate dynamics and implications of this intersection, the article furnishes a profound understanding for policymakers, researchers, and practitioners, equipping them with the tools to navigate and harness the boundless potential of the digital age.

The implications of the insights and principles delineated in this article reverberate significantly across a diverse spectrum of stakeholders. For policymakers, it lays out a clear route towards formulating adaptable regulatory frameworks that both catalyze innovation and ensure the preservation of ethics, privacy, and security within the digital realm. The article accentuates the crucial importance of equal access to the benefits of digitization and emphasizes the urgency of supporting workforce training to forge a robust, adaptable workforce in the face of rapid technological transformations.

Researchers stand positioned to explore innovative methodologies tailored to the digital era, fostering interdisciplinary collaboration and facilitating rigorous analyses of the intricate interplays between NIS and digitization. Concurrently, practitioners can extract actionable insights from the article's recommendations, guiding them in the establishment of collaborative ecosystems, novel research approaches, and policy-driven initiatives that amplify the positive impact of digitization on innovation.

However, the significance of this article extends well beyond its individual sections. It coalesces into a comprehensive narrative that highlights the manifold opportunities and challenges stemming from the fusion of digitization within the National Innovation System. This narrative envisions a future where nations harness the synergies between these domains, positioning

themselves as frontrunners in the global digital economy. The vision of growth propelled by innovation, societal progress, and sustainable development beckons those who grasp and embrace the transformative potential of digitization within the context of the national innovation system.

In culmination, this paper stands as an illuminating source of knowledge, guiding stakeholders along the intricate crossroads of innovation and technology. As the digital age unfolds, the insights encapsulated within will remain a steadfast wellspring of guidance, empowering individuals and nations to flourish in a world where innovation serves as the bedrock of progress. The scientific implications of this research are vast, with potential avenues for further exploration spanning from the intricate mechanisms of collaborative ecosystems to the ethical considerations of digitization, all set against the backdrop of a swiftly changing technological milieu. This study paves the way for future inquiries, enriching the discourse on the interplay between NIS and the digital transformation and offering a roadmap for continual progress in an era where innovation is paramount.

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