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Industry 4.0, Industry 5.0: Freedom or Insecurity for Business?

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Abstract

Purpose –This study investigates the dual influence of Industry 4.0 and Industry 5.0 on business development, with a particular focus on their implications for economic security. It explores how the transition from a purely technology-driven paradigm to a more human-centric one affects business models, innovation strategies, and organizational resilience.

Design/methodology/approach –The article employs a conceptual literature review methodology. It synthesizes findings from peer-reviewed journals, policy papers, and international institutional reports obtained from databases such as Scopus, Web of Science, and Google Scholar. The selection criteria included thematic relevance to digitalization, cyber-physical systems, human-technology interaction, organizational transformation, and strategic foresight.

Findings – The study reveals that Industry 4.0 primarily fosters efficiency through automation, data exchange, and smart systems integration. However, it also raises concerns over cyber vulnerabilities and labor market disruptions. Conversely, Industry 5.0 incorporates human creativity and ethical innovation into digital transformation processes, aiming to balance productivity with inclusiveness and adaptability. Nonetheless, both paradigms introduce complex risks, including cybersecurity threats, social inequality in technology access, and institutional inertia. The findings indicate the urgent need for strategic frameworks that mitigate these risks while fostering technological competitiveness.

Originality – This research is among the first to conceptually contrast Industry 4.0 and 5.0 from the perspective of economic security. It introduces the concept of Quantum 2.0 as a holistic strategic framework for securing business development through cyber-resilience, institutional adaptation, and human-technology co-evolution. The article contributes to the discourse by linking technological progress with socio-economic resilience, offering insights for policymakers and business strategists seeking sustainable and secure industrial transformation.

Keywords: business economic security, digitalization, Industry 4.0, Industry 5.0.

1. Introduction

Over the past decade, digital transformation has emerged as a key driver of socio-economic development, particularly within the frameworks of Industry 4.0 and Industry 5.0. These paradigms represent the evolution of industrial systems toward greater automation, artificial intelligence, and cyber-physical integration (Schwab, 2016; Schwab, 2021). While Industry 4.0 emphasizes technological advancements such as big data, robotics, and machine learning, Industry 5.0 shifts the focus to human-centric innovation, sustainability, and resilience (OECD, 2023; McKinsey, 2021).

A crucial technological vector accelerating these shifts is the development of quantum technologies, known as the

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second quantum revolution or Quantum 2.0. This revolution facilitates a new stage of interaction between physical and digital systems and is increasingly integrated within the logic of Industry 4.0 (Volkova, Gorelova & Pankratova, 2020). According to Rapp, Schneider, and Deutsche Bank AG (2021), the infrastructure for supporting companies in the quantum technology sector is already in place. Furthermore, AiMultiple (Dilmegani, 2023) projects that the quantum computing market will reach USD 949 million by 2025, underscoring the technology's accelerating commercial significance.

However, the same digital innovations that offer new opportunities also generate risks, particularly in terms of economic security. Businesses must now contend with novel threats to their strategic stability and competitiveness that stem from rapid technological change. These include cybersecurity vulnerabilities, the destabilization of existing value chains, and the need for constant adaptation to digital transformation.

This article argues that while quantum and digital technologies pose economic risks, they can also be leveraged to build more resilient and adaptive business models. It highlights the duality of innovation – as both opportunity and threat – and seeks to provide a theoretical framework for understanding the impact of these changes on business security.

The objective of this research is to examine how digital technological transformation – including quantum innovations, automation, and AI – affects business economic security, and to identify strategic responses to mitigate risks and leverage emerging opportunities. The study employs a structured literature review and general scientific methods such as deduction, induction, synthesis, and causal analysis to explore how modern enterprises can navigate digital transformation securely.

The article is structured as follows: Section 2 provides a literature review and theoretical background; Section 3 presents the results of the analysis; Section 4 offers a discussion of the findings and implications; and Section 5 provides conclusions for strategic management of business economic security in the era of digital revolution.

2. Literature Review

The evolution of industrial paradigms – from Industry 4.0 to Industry 5.0 and Society 5.0. – has significantly reshaped organizational structures, technological trajectories, and human roles in production systems. Industry 4.0 initiated a techno-centric transformation of industrial processes, built upon cyber-physical systems, big data analytics, and the integration of smart technologies (Vnukova, 2023). However, scholars now point to a broader shift toward Industry 5.0, which emphasizes the synergy between human creativity and machine intelligence (Hassan et al., 2024).

While Industry 4.0 focuses on automation and efficiency, Industry 5.0 repositions the human as central to innovation, promoting ethically aware, sustainable, and resilient industrial systems. For example, Willetts and Kedzierski (2021) conceptualize Industry 5.0 as "the harmonious interaction of human intelligence with cognitive computing," where technologies of Industry 4.0 are enhanced by digital capabilities that serve social and ethical objectives.

At the same time, the broader notion of Society 5.0 emerges as a strategic vision beyond industrial contexts. Formulated in Japan's Fifth Science and Technology Basic Plan (2017), Society 5.0 aims to construct „a people-centered society that, thanks to the high degree of fusion between cyberspace and physical space, can balance economic development with the solution of social problems by providing goods and services that granularly satisfy a variety latent needs regardless of location, age, gender or language" (Society 5.0: A people-centric super-smart society, 2020). Japan's pivotal contribution to this concept marks an institutional attempt to align technological progress with inclusive development.

In the same publication, the authors emphasize that "in the data-driven society of the 21st century, the most important currency of economic activity is high-quality, relevant, and abundant 'real data.' Data has become so valuable that the claim that business success or failure depends on access to it is by no means an exaggeration" (Society 5.0: A people-centric super-smart society, 2020). This underscores the foundational role of data not only in optimizing industrial performance but also in enabling responsive governance, personalized services, and adaptive infrastructure.

Recent research also highlights the specific technologies underpinning this transformation. Ryvak (2022) identifies artificial intelligence, digital twins, smart materials, and renewable energy systems as core enablers of Industry 5.0. Meanwhile, Xu et al. (2021) highlight that the paradigm promotes systemic resilience, talent development, and environmental sustainability, which are increasingly, regarded as essential conditions for future-oriented economic systems.

This literature suggests a coherent trajectory: digitalization laid the groundwork for Industry 4.0; human-centric design and sustainability define Industry 5.0; and the integrative, value-driven logic of Society 5.0 positions the individual - not just the system - as the primary beneficiary of technological progress.

3. Results

The growing importance of quantum technologies has been underscored by the United Nations' recognition of the International Year of Quantum Science and Technology (2024) on 7th June 2024. The Declaration highlights the profound impact of quantum innovations on nearly all sectors of the global economy, underscoring the transformative potential of quantum science and technology. These technologies are expected to contribute significantly to the achievement of sustainable development goals by reducing industrial risks, enhancing energy efficiency, and stimulating economic growth.

The emergence of the Internet fundamentally reshaped business models and the economic landscape at the global

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and national levels. While it led to the closure of numerous traditional industries, it simultaneously gave rise to new sectors and economic opportunities. The Internet revolutionized communication, redefined business structures, and transformed economic systems. Similarly, the advent of Quantum 2.0 anticipates to provoke equally profound disruptions in the global economy – though with potentially greater risks to business stability.

The advent of the global COVID-19 pandemic has necessitated a major shift in the fundamental approaches to business processes across all business sectors. The transition to remote work has compelled most companies to rethink their business models and approaches to the utilization of computer technology. Businesses experienced an expansion of information flows, necessitating advancements in both technical and technological capacities to manage this growing resource base. This has resulted in the emergence of a range of Internet-based platforms and applications that facilitate communication with a large audience, as well as platforms designed for the collection, accumulation, processing and analysis of information. Furthermore, the transition of businesses to online operations has led to an expansion of information as a resource, which has in turn necessitated improvements in technical and technological capabilities for the management of this ever-increasing information resource. It has been demonstrated that the utilization of artificial intelligence necessitates a considerable input of energy resources. This encompasses not only electricity but also the water employed to cool servers. For example, the ChatGPT-4 language model requires approximately half a liter of water to generate 100 words (Harwell D., 2024, September 18). While quantum technologies are not yet widely integrated into daily life, growing global interest suggests that businesses must begin preparing for their adoption. Enterprises that fail to adapt risk being left behind in the wake of the Quantum 2.0 revolution.

Contemporary scientific discourse is now focused on the transition toward the fifth industrial revolution. It is important to note that the majority of researchers view Industry 5.0 as a consequence of the negative impact of Industry 4.0, particularly in terms of the outflow of employees from the industry (Nahavandi, S., 2019; Leong (Y.K., Tan, J.H., Chew, K.W., & Show, P.L., 2020; Longo, F., Padovano, A., & Umbrello, S., 2020).

The reconfiguration of human capital is now a central issue in the discourse surrounding Industry 5.0. In 2015, Michael Rada – the originator of the Industry 5.0 concept – postulated that the technical and technological support of Industry 4.0 enables systems (e.g. computing devices, robots, etc.) to establish links with one another, thereby enabling them to implement various processes autonomously and independently, negating the need for human input. In other words, employees represent a narrow focus in the industry and can be eliminated. The full quote of the 'father of Industry 5.0', sounds like this: "Since all machines and products will communicate, control and interact with each other, it seems to me that the bottleneck called HUMAN can be eliminated" (Michael Rada, 2015, December 1).

Subsequent research has continued to emphasize the significance of human capital development as a key concern in the Industry 5.0 framework (Maddikunta, P.K.R., Pham, Q.-V., & Ba, P., 2021). In light of these transformations, several crucial aspects of digitalization affecting business economic security have emerged.

Table 1. Key Aspects and Consequences of Business Digitalization

Aspects of Business Digitalization	Implications of Business Digitalization
Transferring business processes to an online format	Creating a digital copy of the business.
The need to change the legal support for the operation of the enterprise in the context of remote work of employees	Disputable issues in calculating the workload of employees and, accordingly, remuneration, as well as the issue of confirming the identity of the person who carried out the activity, etc.
Accumulation of more and more information	The need for greater hardware capacity and faster information computing, including faster internet speeds.
Changes in communication chains	Transition to sharing platforms in the field of communication - increased exposure to cyber risks.
Emergence and development of artificial intelligence	On the one hand, this means accelerating the implementation of such tasks as collecting and analyzing information. On the other hand, it means the risk of losing information resources and obtaining unreliable results, since the algorithm of artificial intelligence is not yet perfect.
Robotization and automation of business processes	Loss of human capital, decrease in employee skills.

Source: developed by authors based on McKinsey & Company (2023); OECD. (2023), Cazzaniga M (2024).

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A synthesis of the effects of digitalization on business and economic stability can be achieved by identifying the following risks (Modern Cyber Threats: How to Protect Employee Accounts - Forbes.ua, 2023) (Fig. 1).

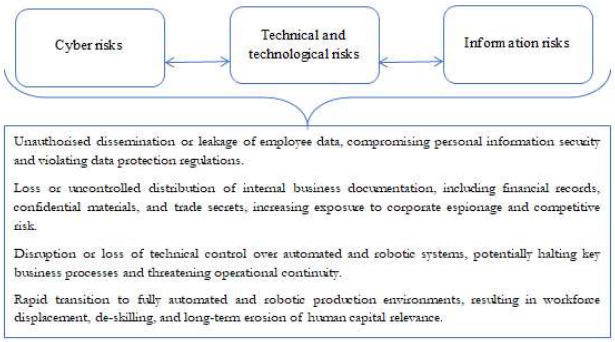

Figure 1. Key Risks to Business Economic Security in the Context of Digitalization
Source: developed by authors based on Izhevsky P., Samaricheva T., & Kudelsky V. (2024),

OECD. (2023), (Qin, Xu, Wang, & Skare, 2023)

As illustrated in Fig. 1, the digitalization of businesses, particularly under the framework of Industry 4.0, has introduced a range of risks related to cybersecurity, data integrity, and economic stability (Modern Cyber Threats – Forbes. ua, 2023). These risks predominantly stem from the development of cyber-physical systems and digital twins, rather than from traditional staffing or skill-based concerns.

The mere creation of digital copies and the use of innovations in robotics and automation offers many opportunities.

- Improving the implementation of business processes through the use of digital technologies, in particular, artificial intelligence in the decision-making system;
- Development of production through the use of robotic systems;
- Reducing the cost of goods and services through robotics and automation;
- Improving the energy efficiency of business activities, etc.

However, all of the above can be more accurately characterized as falling within the framework of the Industry 4.0 concept, which prioritizes production growth and market expansion through digital technologies (Hassan, Zardari, Farooq, Alansari, & Nagro, 2024). It can be argued that the Fourth industrial revolution has led to the need for consumers to purchase goods in a more systematic and uninterrupted manner, due to the ever-expanding range of products (Schwab K. 2016). In addition to widespread unemployment and a decline in overall consumer income levels, the world is experiencing over-consumption and, as a result, unsustainable use of resources, including energy resources (Qin Xu, Wang, & Skare, 2023). If we summarize the above, the consequences of the era of industrial development in the context of ‚business-consumer' can be described as a sequence:

Development of industrialization: (increasing the quantity of goods produced, creating the need for the consumer to constantly buy new goods) + (increasing energy consumption in production, increasing the cost of goods) + (increasing global inflation, decreasing the quality of personal income, decreasing purchasing power) = creation and accumulation of consumer debt.

The current situation can be described as a precursor to Industry 5.0, which aims to achieve sustainable development through the introduction of human-centered production. Assuming that the actual transition of society to the beginning of the Fifth Industrial Revolution is not far away, it is already clear what companies will face in the new paradigm of industrial development. The first is the development of artificial intelligence, and the second is how society will use it (Zhao and Fariñas 2022). It is possible to identify the main challenges that the development of artificial intelligence poses for businesses, and try to describe the opportunities that it opens up.

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Table 2. Key Business Challenges and Opportunities Related to the Development of Artificial Intelligence

Key Challenges	Key Opportunities
Autonomous cyber-physical systems may function independently of human input, reducing the role of human labor.	Redesigning job roles to focus on oversight, ethics, and AI-human interaction; attracting investment in AI-augmented sectors such as quantum technology research.
Unemployment and reduced consumer purchasing power due to automation and lack of regulatory protections.	Reduction in production costs through automation can allow for price reductions and reallocation of labor to creative, strategic, or care-related roles.
Decline in employee skills and relevance due to reduced human involvement in automated processes.	Development of reskilling and upskilling programs to align with AI-based work environments and mitigate human error risks.
High capital requirements and technological complexity of AI implementation.	Real-time monitoring and performance optimisation through digital twins, increasing operational efficiency and strategic control.
Heavy energy demands of AI infrastructure, including electricity and cooling.	Incorporation of energy-efficient AI systems and optimization of tools that reduce operational waste and improve sustainability reporting.
Increased importance of cybersecurity as a component of business economic security.	Development of integrated cybersecurity strategies and AI-based threat detection systems that strengthen digital trust, protect data assets, and enhance business continuity.
Deterioration in the quality of education and reduced research capacity in traditional formats.	Investment in AI-powered education platforms and research analytics to personalize learning and enhance R&D productivity.

Source: developed by authors based on Pereira A. G. (2020), Schwab K. (2016, 2021).

4. Discussion

The results of this study highlight the complex and often contradictory impact of digitalization and new technologies on the economic security of businesses. The analysis showed that while the transition from Industry 4.0 to Industry 5.0 opens up new avenues for innovation and efficiency, it also creates critical vulnerabilities that need to be addressed at both the organizational and legal levels.

In line with the study's objective of investigating how technological transformations are impacting security-oriented business development, the results demonstrate that the integration of artificial intelligence, automation, and future quantum innovations is changing fundamental business processes. As shown in Table 1, digitalization is impacting communication, compliance, information management, and workforce composition. These changes increase operational efficiency, but also increase the impact of cyberthreats, reduce reliance on human capital, and require new infrastructure and regulatory measures.

Table 2 complements this perspective by showing that for almost every identified challenge – from skill loss to energy dependency – there is a potential counterbalance in the form of innovation, strategic investment, or policy adaptation. For example, concerns about the shrinking workforce due to automation could be partially mitigated through targeted reskilling and job creation initiatives focused on AI oversight, ethics, and so on. Similarly, the growing importance of cybersecurity provides an opportunity to develop integrated defenses that enhance digital trust and business resilience.

These findings reinforce the argument that business security in the digital age cannot rely on static risk-reduction strategies. Instead, companies must adopt dynamic, adaptive approaches – what might be called strategic antifragility – that not only manage risk but also use it to create new forms of value. This is consistent with the evolving conceptual shift from reactive to proactive security management models, especially in data-intensive economies.

From a legal perspective, the analysis highlights the need to create regulatory frameworks that address the socio-economic implications of automation and digital dependency. These include unemployment protection, data sovereignty provisions, and guidance on the ethical implementation of AI. Furthermore, as countries prepare for the wider adoption of quantum technologies, there is an urgent need to establish legal norms and infrastructure that support equal access and minimize the concentration of power among a few technological players.

In practice, enterprises should view digital transformation not as a discrete transition but as a continuous strategic process. The ability to integrate new technologies while maintaining resilience and trust will increasingly determine competitive

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advantage. Businesses that treat economic security as a core strategic function, rather than a peripheral one, will be better equipped to overcome disruptions and seize new market opportunities.

Finally, this study points to several directions for further study. First, there is a need for empirical testing of the proposed risk-opportunity pairs across sectors and national contexts. Second, the implications of quantum technologies for SMEs remain understudied. Third, the role of human capital development in Industry 5.0, especially in non-manufacturing sectors, requires deeper theoretical and practical research.

Finally, the study contributes to the discourse on economic security in the context of technological transformation. By viewing digitalization as both a risk and a strategic opportunity, it encourages a more balanced, forward-looking approach to managing business development in the era of Industry 5.0 and Quantum 2.0.

5. Conclusion

This study examines the implications of digitalization, Industry 4.0, Industry 5.0, and the expected transition to Quantum 2.0 for the economic security of businesses. The study's findings suggest that while these technological shifts create significant opportunities in terms of efficiency, automation, and data integration, they also expose businesses to a growing range of risks, particularly in areas such as cybersecurity, workforce transformation, and regulatory uncertainty.

A structured analysis of risks and opportunities has shown that digital and quantum technologies have the potential to enhance business resilience, provided that organizations adopt flexible and adaptive strategies. The study illustrates the need to implement new models of business development and economic security that will not only withstand disruptions but also use them as a foundation for transformation.

While the study addresses possible future developments, such as the growing influence of artificial intelligence and the commercialization of quantum computing, these points should be interpreted as forward-looking hypotheses rather than definitive predictions. The extent to which these technologies will change business practices remains a matter of ongoing research, regulatory evolution, and technological maturity. Overall, the transition from Industry 4.0 to 5.0 should not be seen as a linear or automatic process, but rather as a strategic choice that requires rethinking fundamental assumptions about value creation, human participation, and systemic sustainability. Business and policy leaders must work in tandem to ensure that innovation supports not only growth, but also social responsibility, equity, and long-term economic security.

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Conflict of Interest

The authors hereby declare that this article was not submitted or published elsewhere.

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