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Digitalization of the Economy as a Direction of Scientific and Technological Development of the Country

Aleksey Polovyan[1][a] Lyudmila Shabalina[2][b] Galina Shavkun [2][c] Karina Sinitsyna[3][d] and Mark Timko [2][e]

[1]*Department of Financial and Economic Research, Economic Research Institute, Universitetskaya Street, Donetsk, Russia*
[2]*Department of Planning of Socio-economic Development of Territorial Systems, Economic Research Institute, Universitetskaya Street, Donetsk, Russia*
[3]*Department of Interdisciplinary Scientific Research, Innovation and Training of Scientific and Pedagogical Personnel, Economic Research Institute, Universitetskaya Street, Donetsk, Russia*
polovyan@yandex.ru, luda_2270@mail.ru, galina.shavkun@mail.ru, sinitsinak@mail.ru, mark26328@mail.ru

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Abstract: Digitalization of the economy has ceased to be merely a technological trend – it has become the central vector of scientific and technological development of the 21st century, redefining the foundations of production, knowledge exchange, resource distribution, and capital formation. With the rapid adoption of artificial intelligence, big data, the Internet of Things, and quantum computing, a fundamental question arises: how can we ensure that digital transformation contributes not only to economic growth but also to social sustainability, inclusiveness, and ethical responsibility? This article analyzes the dual nature of digitalization – as both an object and a driver of innovation – and explores the conditions under which its potential can be fully realized. Special attention is paid to the transformation of capital in the digital age, emerging macroeconomic paradoxes, the role of state policy in shaping digital ecosystems, and the growing importance of human capital with an emphasis on creativity, digital literacy, and lifelong learning. Based on a systematic review of current studies and strategic documents of international organizations, it is shown that the success of digital transformation depends less on the availability of technologies than on the quality of institutions, education systems, and society's ability to establish new norms under technological uncertainty. The article contributes to an interdisciplinary understanding of digitalization as a complex socio-technical process requiring synergy among science, policy, and economics.

[a] https://orcid.org/0000-0001-8570-6202
[b] https://orcid.org/0000-0002-3621-6466
[c] https://orcid.org/0000-0002-0401-7163
[d] https://orcid.org/0000-0002-4893-5089
[e] https://orcid.org/0009-0000-3099-7583

1 INTRODUCTION

The digitalization of the economy represents one of the key directions of modern scientific and technological development, driven by the rapid transformation of production, management, and communication processes under the influence of digital technologies. In the context of the Fourth Industrial Revolution – characterized by the synergy of physical, digital, and biological systems – digitalization acts not only as a tool for increasing the efficiency of economic activity but also as a system-forming factor defining new paradigms of growth, competitiveness, and sustainable development of national economies. Its relevance stems from the global trend toward the integration of artificial intelligence, big data, the Internet of Things, blockchain, and other innovative solutions into key sectors of the economy – from industry and agriculture to finance and public administration.

The scientific interest in studying economic digitalization is determined by the need for theoretical comprehension of its role in shaping technological sovereignty, ensuring structural modernization, and creating conditions for inclusive growth. In this context, an interdisciplinary approach becomes particularly important, combining economic, technological, social, and institutional aspects of digital transformation. Such an approach makes it possible to comprehensively assess both the potential benefits and the accompanying risks of this process.

2 MATERIALS AND METHODS

The study employed an interdisciplinary approach combining theoretical analysis, a systematic literature review, and a comparative-analytical examination of international strategic documents. The empirical base consisted of publications in peer-reviewed academic journals, monographs by leading researchers in the field of the digital economy, and official reports of international organizations – the OECD, the World Bank, the European Commission, and the G20. Sources were selected based on scientific reliability, relevance (mainly publications from 2015–2025), and representativeness of key theoretical and empirical approaches to analyzing digital transformation.

The methodological framework was built on qualitative content analysis of documents and academic texts aimed at identifying dominant conceptual frameworks, discussion areas, and trends in interpreting the role of digitalization within scientific and technological development. Special attention was given to categorical analysis of such concepts as “digital capital”, “digital ecosystem”, “productivity paradox”, and “human capital in the digital economy”, which made it possible to reconstruct the evolution of theoretical models explaining the mechanisms of economic transformation under the influence of digital technologies.

To assess the macroeconomic effects of digitalization, data from international comparative studies were used. The analysis applied a comparative-descriptive method focused on identifying causal relationships between the level of digital maturity of economies and indicators of productivity, resilience, and inclusiveness of growth.

An institutional approach was also employed, allowing digitalization to be viewed not only as a technological but also as a socio-institutional process dependent on the quality of legal norms, regulatory practices, and educational systems. In combination, these methods provided theoretical depth and analytical rigor, enabling a holistic understanding of digitalization as a complex direction of scientific and technological development.

3 RESULTS

Digitalization of the economy, as a direction of scientific and technological development, is a complex and multifaceted process encompassing the transformation of production, management, financial, and social systems under the influence of digital technologies. At the core of this process lies the integration of advanced technological solutions – such as artificial intelligence (AI), machine learning, the Internet of Things, cloud computing, blockchain, and platform-based business models – into economic structures at both the micro and macro levels (Brynjolfsson & McAfee, 2014). This integration not only increases labor productivity and optimizes supply chains but also creates new markets, changes the nature of employment, and transforms the institutional environment of the economy.

One of the key aspects of digital transformation is the fundamental change in the nature of capital as an economic category. In classical economic theory, capital was traditionally viewed through the prism of physical assets (buildings, equipment, infrastructure) and human capital (knowledge, skills, experience).

However, in the digital era, a new, qualitatively distinct type of capital emerges – digital capital, which includes data, algorithms, software, digital infrastructure (cloud platforms, data centers, telecommunication networks), and intangible assets such as intellectual property, digital brands, and network effects (World Bank, 2021). Data, in particular, acquire the status of a strategic economic resource comparable in importance to oil in the industrial era or land in the agrarian one. Their value is determined not only by volume but also by processing speed, analytical depth, and their ability to generate predictive insights that improve decision-making efficiency at both enterprise and national levels. In this regard, platform-based companies whose competitiveness is built not on ownership of physical assets but on control over data and algorithms gain particular importance.

Yet the transformation of capital in the digital age is associated with a number of systemic challenges, especially in regulation. The problem of balancing innovation incentives with the protection of public interests becomes critical. As Zuboff (2019) notes, commercialization of personal data in the context of surveillance capitalism generates new forms of exploitation and threatens fundamental citizens' rights, including privacy and informational autonomy. The absence of transparent and effective digital governance institutions – such as independent data regulators, antimonopoly authorities with digital expertise, and mechanisms of cybersecurity and digital identification – creates favorable conditions for the concentration of market power in the hands of a few global platforms. This, in turn, increases the risks of monopolization, competition suppression, digital inequality, and declining public trust in technological innovation. Uneven access to digital resources may also exacerbate regional and social disparities, marginalizing groups or territories unable to adapt to new conditions.

At the macroeconomic level, digitalization acts as a powerful yet ambiguous driver of growth. On the one hand, according to OECD (2020), countries actively investing in digital technologies and implementing them in industry, agriculture, logistics, and services demonstrate higher gross domestic product growth, improved labor productivity, and greater resilience to external shocks. Digital technologies reduce transaction costs, increase flexibility, optimize resource allocation, and create new forms of employment and entrepreneurship. On the other hand, the so-called "productivity paradox" (Syverson, 2017) indicates that, despite widespread IT adoption, aggregate labor productivity in developed countries grows more slowly than expected. This shows that technological progress alone is insufficient for macroeconomic gains. Realizing the potential of digitalization requires deep structural changes: organizational redesign, education-system modernization, new legal frameworks, and the development of complementary technologies and competencies. Without such transformations, digital investments may prove inefficient or even counterproductive, widening the gap between technological leaders and outsiders at both firm and country levels.

Thus, digitalization transforms not only the technical base of production but also the very logic of markets, resource allocation, and value creation. The shift to a data- and algorithm-based economy requires rethinking traditional categories – property, competition, labor, and capital – and developing new methodological and institutional frameworks that ensure sustainable, inclusive, and ethically responsible development in the digital age.

From the perspective of scientific and technological development, the digitalization of the economy acts not merely as a passive result of technological progress but as an active catalyst and, simultaneously, an object of innovative transformation. On the one hand, the very logic of the digital economy generates demand for fundamental and applied research in advanced fields of science and technology. These include:

- quantum computing, which can radically accelerate the processing of complex computational tasks,
- neuromorphic architectures, simulating biological neural networks and opening new horizons for the creation of energy-efficient AI systems,
- artificial intelligence ethics, cybersecurity, and protection of critical digital infrastructure, which are becoming increasingly important as society's dependence on digital systems grows (European Commission, 2020).

These areas require not only technical breakthroughs but also interdisciplinary synthesis – the combination of expertise in computer science, neuroscience, philosophy, law, and sociology – thus forming a new paradigm of scientific knowledge oriented toward addressing complex socio-technological challenges.

On the other hand, digitalization itself creates an unprecedented infrastructural foundation for accelerating scientific discoveries and technological transfer. Modern digital platforms provide scientists

and engineers with access to distributed computing resources, open-data repositories, real-time collaboration tools, and virtual prototyping capabilities. Simulation modeling, digital twins of physical objects and processes, and machine-learning methods make it possible to shorten innovation cycles, reduce risks and costs, and improve the reproducibility of research results. Importantly, open science, supported by digital tools, promotes the democratization of knowledge, transparency of the scientific process, and faster commercialization of research – all of which enhance feedback between science, business, and society (European Commission, 2020).

However, this potential cannot be realized without strategic and coordinated participation by the state. State policy should be aimed not only at financing research and digital infrastructure development but also at creating integrated digital ecosystems – sustainable, interconnected complexes that include not only technologies but also legal frameworks, data-governance institutions, intellectual-property protection mechanisms, interoperability standards, and educational and innovation networks (OECD, 2019). Such ecosystems foster an environment conducive to experimentation, reduce entry barriers for startups and small enterprises, stimulate cross-sector collaboration, and ensure a balance between innovation and social safeguards. Without a systemic approach emphasizing synergy among government, the private sector, academia, and civil society, digitalization risks becoming a fragmented and uncoordinated process incapable of producing lasting socio-economic effects.

A particularly important role in the functioning and development of such ecosystems belongs to human capital, which, under digital transformation, acquires a new dimension. The digital economy places qualitatively new demands on the workforce: beyond professional expertise, digital literacy, adaptability, lifelong learning, and interdisciplinary thinking are increasingly essential. Amid accelerating automation and robotization of routine tasks, so-called soft skills – critical thinking, creativity, emotional intelligence, communication, and teamwork – become vital (Autor, 2015). These competencies are key ones not only for maintaining competitiveness in the labor market but also for participating in digital governance, shaping ethical standards, and exercising social oversight over technology. Accordingly, modernization of educational systems – from preschool to postgraduate levels – and the development of flexible, practice-oriented programs for retraining and up skilling acquire strategic importance. Only under synchronized development of the technological base and human capital economic digitalization can become a genuinely sustainable and inclusive vector of scientific and technological development, capable of generating not only economic growth but also social progress.

4 DISCUSSION

The discussion of the presented material highlights several key theoretical and practical issues concerning the role of digitalization in scientific and technological development. First of all, despite broad recognition of digitalization as a strategic vector of economic modernization, there is still no consensus on its theoretical and methodological foundations. A major debate concerns whether digitalization represents a qualitatively new technological paradigm or a continuation and acceleration of processes initiated during the information revolution. Some scholars (e.g., Perez, 2010) argue that digital transformation meets the criteria of a new techno-economic paradigm, while others (Bresnahan & Trajtenberg, 1995) see it as an evolutionary extension of previous IT waves without generating radical structural shifts. This debate is critical for forecasting long-term macroeconomic effects of digitalization and for shaping public policy.

A second key area of discussion concerns the impact of digitalization on productivity and economic growth. Despite theoretical expectations and specific successful cases (e.g., in fintech or e-commerce), empirical data remain ambiguous. The persistence of the "productivity paradox" (Syverson, 2017) challenges the assumption of an automatic "technology → growth" relationship. This highlights the strong dependence of economic outcomes on contextual factors: institutional quality, organizational digital maturity, adequacy of regulatory frameworks, and human-capital capacity. Consequently, the role of the state becomes highly debated. While many experts emphasize the need to develop "digital ecosystems" (OECD, 2019), the degree and forms of state intervention remain contested. On one hand, active government support – through investments in infrastructure, standardization, and education – is necessary. On the other hand, excessive regulation may suppress innovation and create barriers to competition,

especially in a global context dominated by transnational digital platforms.

An equally contentious issue concerns the redistributive consequences of digitalization. While aggregate indicators (gross domestic product, overall productivity) may show positive effects, at the micro level digital transformation often leads to labor-market polarization, income inequality, and vulnerability of certain worker groups (Acemoglu & Restrepo, 2019). The central dilemma arises: how can efficiency and innovation be reconciled with principles of social justice and inclusiveness? In this context, the debate about digital capital (World Bank, 2021) acquires not only economic but also ethical significance. Control over data, algorithms, and digital platforms is concentrated among a limited number of actors, threatening democratic norms and the equitable distribution of benefits from digital progress.

Finally, the relationship between science and the digital economy remains a subject of debate. If digitalization indeed serves as both an object and a driver of scientific and technological development, a new question arises about the evolving role of science in the digital age: does science become a tool serving market demands, or does it retain autonomy in posing fundamental questions? While open science and digital research infrastructures undoubtedly expand opportunities for knowledge transfer, they may also encourage the commercialization of scientific processes and shift emphasis from fundamental to applied research. Hence, developing new ethical and institutional frameworks ensuring balance between innovation dynamics, scientific autonomy, and societal interests becomes increasingly vital.

5 CONCLUSIONS

Digitalization of the economy is not merely a technological trend but a fundamental vector of scientific and technological development that transforms economic structures, institutional frameworks, and the very logic of production, distribution, and consumption. It functions simultaneously as the result of accumulated scientific progress and as a powerful driver of further innovation, requiring breakthrough research in areas such as artificial intelligence, cybersecurity, quantum technologies, and data ethics, as well as the creation of new infrastructural and regulatory foundations. A key element of this transformation is the rethinking of the nature of capital, wherein data and algorithms become strategic resources comparable to traditional production factors. However, the potential of digitalization can be realized only through a comprehensive and balanced approach that includes not only technological advancement but also the modernization of human capital, the establishment of effective institutions of digital governance, and the implementation of coherent state policies aimed at building sustainable and inclusive digital ecosystems

Without consideration of social, ethical, and institutional dimensions, digital transformation risks exacerbating existing inequalities, intensifying monopolization, and undermining public trust in technological innovation. Thus, the successful integration of digitalization into national development strategies requires interdisciplinary synthesis, strategic vision, and continuous scientific support, ensuring not only economic efficiency but also social sustainability amid profound technological uncertainty.

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