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## The Digitalization and Smart Specialization in Regional Economic Ecosystems: Integrating AI Technologies for Sustainable Development

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### ABSTRACT

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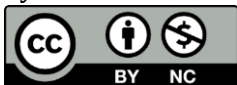
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The article examines digitalization and smart specialization as complementary mechanisms for transforming Ukraine's regional economic ecosystems under technological instability and martial law. Smart specialization is considered "architectonics" of economic interaction, where local resources gain new significance through alignment with human capital, entrepreneurship, and technology, generating long-term structural development impulses. Institutional trust serves as a key channel for communication and innovation. Digitalization is not merely the digitization of services but a foundation for integration processes that create a new socio-economic experience and redefine the roles of government, business, and communities. The concept of digital ecology encompasses coordination of information flows, interaction speed, and accumulation of local knowledge, reducing developmental entropy and enabling controlled scenarios. Analysis of the legal framework for smart specialization shows that its effectiveness depends on alignment with informal practices, local initiative, and risk readiness. Under these conditions, a new type of collective entrepreneurship emerges, creating not only market niches but also communicative bridges between local and global spaces. Integration of artificial intelligence in regional governance enables early detection of systemic weaknesses and optimization of resources through predictive models and policy evaluation algorithms. The dynamics of the Regional Digitalization Index in Q1–Q2 2025 demonstrate uneven adaptation, reflecting local developmental specificity. During wartime, digitalization acts as a mechanism of social solidarity, supporting remote employment, internally displaced persons, and adaptation of services to limited resources. The symbiosis of digitalization and smart specialization creates adaptive and technologically resilient economic systems, where digitalization ensures rapid response and smart specialization ensures sensitivity to opportunities. This enables regions to overcome exogenous shocks and integrate into global innovation chains.



### KEYWORDS

public management, public policy, smart specialisation, international standards, region, regional development, digitalisation, regional economic ecosystem, artificial intelligence, digital maturity, sustainable development, innovation clusters, regional policy.



## Цифровізація та смарт-спеціалізація в регіональних економічних екосистемах: інтеграція технологій ШІ для сталого розвитку

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### СТАТТЯ

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Стаття досліджує цифровізацію та смарт-спеціалізацію як взаємодоповнювані механізми трансформації регіональних економічних екосистем України в умовах технологічної нестабільності та воєнного стану. Смарт-спеціалізація постає як «архітектоніка» економічної взаємодії, де локальні ресурси набувають нової ролі через узгодження з людським капіталом, підприємницьким потенціалом та інтелектуальними технологіями, створюючи довготривалі структурні імпульси розвитку. Інституційна довіра виступає ключовим каналом для комунікації та інновацій. Цифровізація розглядається не лише як оцифрування послуг, а як фундамент інтеграційних процесів, що формує новий соціально-економічний досвід та змінює ролі держави, бізнесу та громади. Концепт цифрової екології охоплює координацію інформаційних потоків, швидкість взаємодії та акумуляцію локальних знань, що дозволяє зменшувати ентропію розвитку та створювати керовані сценарії. Аналіз нормативно-правової основи смарт-спеціалізації показує, що ефективність законодавства залежить від узгодження з неформальними практиками, локальною ініціативою та готовністю до ризику. В таких умовах формується новий тип підприємництва – колективний, що створює не лише ринкові ніші, а й комунікативні мости між локальним та глобальним простором. Інтеграція штучного інтелекту в регіональне управління дозволяє виявляти системні слабкості на ранніх етапах та оптимізувати ресурси за допомогою прогностичних моделей та алгоритмів оцінювання політик. Динаміка Індексу цифровізації регіонів за I–II квартали 2025 року демонструє нерівномірність адаптації, що підкреслює специфіку локального розвитку. У воєнний період цифровізація виступає механізмом соціальної солідарності, забезпечуючи дистанційну зайнятість, підтримку ВПО та адаптацію сервісів до обмежених ресурсів. Симбіоз цифровізації та смарт-спеціалізації формує адаптивні та технологічно стійкі економічні системи, де перша забезпечує швидкість реагування, а друга – чутливість до можливостей. Це дає змогу регіонам долати екзогенні шоки та інтегруватися у глобальні інноваційні ланцюги.



### КЛЮЧОВІ СЛОВА

публічне управління, державна політика, смарт-спеціалізація, міжнародні стандарти, регіон, регіональний розвиток, цифровізація, регіональна економічна екосистема, штучний інтелект, цифрова зрілість, сталий розвиток, інноваційні кластери, регіональна політика.

## **1. Introduction**

Digitalization of regional economic ecosystems and the introduction of smart specialization are becoming one of the main modernization strategies, as they allow combining technological potential with local production, personnel, and institutional features of the regions. The concept of smart specialisation assumes that regions identify their competitive advantages and concentrate resources on priority areas of innovation, which makes it possible to effectively use the funds of the European Union (EU) cohesion policy [7].

In modern conditions, one of the defining priority areas can be artificial intelligence – it can serve as a catalyst for new high-tech clusters, digital services and increasing the competitiveness of the economy. At the same time, international standards for AI regulation – in particular the Organisation for Economic Co-operation and Development (OECD) and legislative initiatives of the EU Artificial Intelligence Act – establish a framework of accountability, transparency and security that should be integrated into regional strategies [8].

However, it is worth noting that in practice there is a significant gap between the European recommendations and the capabilities of the regions: uneven institutional capacity, lack of funding, lack of coordination between stakeholders – all this slows down the translation of the concept of smart specialization using AI at the local level. This is evidenced by both analytical studies and regional strategies that do not cover the comprehensive integration of digital technologies [7].

In addition, there is the problem of the lack of coordinated mechanisms for monitoring and evaluating the impact of smart AI specialization initiatives on regional development, which makes it impossible to identify bottlenecks and adjust policies in a timely manner. Without such mechanisms, there is a growing risk that investments in technology will not lead to the expected socio-economic effect.

Thus, the essence of the problem lies in the question of how to develop and implement regional smart specialization strategies using AI that would comply with international norms and standards, but at the same time would be adapted to local institutional conditions, resource constraints, and the needs of the business environment.

## **2. Literature Review**

The problem of introducing smart specialization in the regions of Ukraine and integrating artificial intelligence into this system is of particular relevance, as it directly affects the efficiency of regional development and meets international standards of innovation policy. In the context of martial law, smart specialization becomes not just a tool of economic stimulation, but a mechanism for increasing the resilience of regional economic ecosystems, capable of combining scientific potential, entrepreneurial initiative, and state resources into a single system.

Baranovskyi [2] notes that smart specialization contributes to the activation of regional development, emphasizing the importance of interregional coordination and analytical support. At the same time, Brych et al. [3] emphasize the need for strategic consistency, since clearly defined areas of territorial development allow optimizing the use of resources and stimulating the activity of enterprises and research centers. In particular, this approach demonstrates that smart specialization is not a formal declaration, but a living tool capable of adapting to local challenges and limitations inherent in the conditions of war.

Varuk [18] focuses on the social effect of the implementation of smart strategies: increasing the well-being of residents of amalgamated territorial communities, creating local innovation ecosystems and developing entrepreneurship. Holodnytskyi [8] notes that the integration of artificial intelligence into regional strategies requires a unified definition and compliance with international standards, such as the EU AI Act, which provides a regulatory framework for digital transformation and data-driven strategic decision-making.

The peculiarities of the implementation of the concept of smart specialization in Ukraine are highlighted by Emelianov and Kozlova [5], emphasizing the importance of a systematic approach, clustering of innovative assets and the development of knowledge-intensive sectors. Ishchuk and Sozanskyi [10] point out the need to take into account regional priorities and resource potential when

choosing areas of smart specialization, which allows to ensure the realism and effectiveness of strategies even in difficult conditions.

In the practical aspect, Oleshko et al. [16] emphasize the prospects of smart specialization as a tool for maintaining the economic stability of regions during martial law, where digital technologies are becoming key to rapid adaptation to new challenges.

Shvets and Shevtsova [17] show that the development of entrepreneurship is a critical component of smart specialization: active interaction between the state and the private sector forms a viable innovation ecosystem. Analytical systems described by Alfeo et al. [1], allow evaluating the dynamics of technological indicators and timely adjustment of development strategies, ensuring a balance between economic, social and technological goals.

The EU experience, in particular the conclusions of the European audit [7] and the study of social sustainability of digital transformations by Nosratabadi et al. [15], can be adapted to Ukrainian conditions, taking into account national characteristics, security needs and sustainable development. At the same time, modern research by Huk and Zeynalov [9] and Kindzerski [11] emphasizes the importance of leveling regional imbalances and integrating innovation strategies into the national economy, which is key to maintaining economic resilience during martial law.

Despite the progress in digitalization and the development of innovative platforms, there are still problems with the comprehensive effectiveness of smart strategies.

### **3. Problem Statement**

The purpose of the study is to substantiate the mechanisms of digitalization and the introduction of smart specialization in regional economic ecosystems through the integration of artificial intelligence technologies, aimed at increasing the efficiency of innovation development management, optimizing interaction between public, private and scientific institutions and ensuring sustainable socio-economic development of regions, taking into account local resources, institutional capacity and international standards.

### **4. Methods and Materials**

First of all, the article uses a system-analytical approach, which made it possible to study intelligent specialization as a cumulative socio-economic entity that closely intertwines resources, institutions, human capital and advanced digital technologies. Moreover, it made it possible to identify correlations between innovative management tools and tools for the formation of sustainable development models necessary for regional development. To clearly present the legislative framework for digital transformation and smart specialization, an in-depth study of strategic documents and regulations was conducted. This was done mainly through the analysis of the State Strategy for Regional Development and the Action Plan for its implementation, in accordance with the Resolution of the Cabinet of Ministers of Ukraine No. 931 of 11.11.2015, materials that methodologically regulate reasonable specialization at the level of the territorial community. This thorough research contributed to the recognition of formal mechanisms critical for supervision, institutional support and evaluation of the success of digital transitions in regional governance. The comparative analysis contributed to the identification of appropriate models for the implementation of regional innovation policy, as well as assessment tools in terms of algorithmization of management processes and successful practices aimed at integrating artificial intelligence technologies into public administration systems, which can also be adapted to national specifics in Ukraine. To assess the digital maturity of regions, a statistical method was used, based on the analysis of indicators obtained from the Digital Transformation Index of Regions and Territorial Communities. For a deeper analysis of development management models – first through traditional procedures, and later from the angle of their cognitive foundations – it was necessary to combine structural and functional analysis with logical-system approaches. These methods have provided important guidelines for understanding the links between digital tools, management processes, and local economic dynamics across sectors. They also contributed to the study of the use of digital analytics, modeling the needs of the population, geographic information systems and crisis management tools to create adaptive management solutions that can effectively respond to changing conditions. It is worth noting that the variety of methods used in this study made it possible to cover various aspects of the topic and combine theoretical provisions (digitalization; smart specialization)

with empirical data. This systematic approach helped to recognize systemic trends in the evolution of digital infrastructure, as well as to identify the significant potential of AI technologies to change value-added activities of regional economic ecosystems, which would lead to the sustainable development of systems.

## **5. Results and Discussion**

The latest stage of transformation of regional economic ecosystems of Ukraine is characterized by the search not just for innovative tools to increase the competitiveness of territories, but rather for comprehensive strategies that can create synergy between local resources, human capital and technological potential. In this context, smart specialization acts not only as a method of strategic planning, but as a catalyst for structural transformations, which forms the prerequisites for long-term economic and social development at the local level. It should be noted that the implementation of the smart specialization strategy has a direct impact on the well-being of residents of amalgamated territorial communities, as it allows purposefully concentrating resources on priority areas, stimulating the creation of high-quality jobs and increasing the overall efficiency of the local economy [18, p. 339]. At the same time, it should be emphasized that without the active and systematic use of digital technologies that can not only automate management processes, but also provide analytical forecasting, risk assessment and optimization of the resource potential of regions, the effect of implementing smart specialization strategies remains fragmentary.

The regulatory environment forms a solid foundation for the implementation of smart specialization in Ukraine. The State Strategy for Regional Development and the Action Plan for its implementation, approved by the Resolution of the Cabinet of Ministers of Ukraine No. 931 of November 11, 2015, determine the key mechanisms for monitoring and evaluating the effectiveness of strategic decisions [4]. It is important that the document provides for the harmonization of national policy with initiatives at the community level, which allows taking into account local characteristics, social needs, and the historical and cultural potential of territories, ensuring transparency and accountability of resource allocation processes.

At the practical level, the development of entrepreneurship is a determining factor in the integration of smart specialization into regional economic ecosystems. The research of Shvets and Shevtsova demonstrates that entrepreneurial initiatives, supported by digital platforms and analytical tools, create the effect of synergy between scientific developments, local resources and market opportunities, which significantly increases the effectiveness of the implementation of strategic plans [17, p. 54–55]. We believe that this is manifested mainly in industry, agro-industrial complex and the service sector, where digital technologies allow for targeted demand analysis, assessment of the potential of regions and prompt adjustment of development strategies in accordance with changes in market conditions and socio-economic challenges.

Modern scientific and practical discussion focuses on the critical role of artificial intelligence (AI) technologies, which are not limited to routine automation: they create prerequisites for the formation of predictable models of economic behavior, assessment of potential effects of project implementation, minimization of risks of inefficient use of resources and increasing the transparency of management decisions [3, p. 54]. Taking into account the above aspects, the combination of smart specialization with digitalization and AI forms a unique, integrated approach to ensuring the sustainable development of regions, able to take into account economic, social, cultural, and historical-territorial features, as well as adapt to dynamic changes in the external environment. Thus, the effective implementation of smart specialization is no longer a matter of planning – it is becoming a complex socio-technological practice that can transform regional economic systems into competitive, technologically sustainable and socially inclusive structures.

In recent years, digitalization in Ukraine has been taking on signs of not just a technical update, but a transformational shift that changes the very logic of interaction between the state, business and community. It has ceased to be a set of local projects devoid of consistency and is gradually turning into an integral strategic vector of state policy, which has its own measurable indicators and management mechanisms. This process is not reduced to the modernization of services or the introduction of electronic documents – it forms a new culture of regional development, where digital interaction becomes an integral element of economic dynamics and social sustainability. The Ministry of Digital Transformation of Ukraine plays the role of coordinator and bearer of the methodological framework of

digital policy, implementing the Diia.Digital Community platform and updating the data of the Index of Digitalization of Regions and Communities of Ukraine on a quarterly basis [5].

In Table 1 reveals the features of assessing the dynamics of technological indicators in the context of smart specialization for the I–II quarter of 2025.

**Table 1. Adaptive system for assessing the dynamics of technological indicators in the context of smart specialization for the I-II quarters. 2025**

| Category                         | Measurement Time | Average score | Leaders (highest score)  |
|----------------------------------|------------------|---------------|--|
| <b>Regions (regions)</b>         | I sq. m. 2025    | 30/100        | Dnipropetrovsk 43, Lviv 43, Ternopil 42  |
| <b>Regions (regions)</b>         | II quarter. 2025 | 38/100        | Lvivska 54, Dnipropetrovsk 52, Poltava 50  |
| <b>Communities (territorial)</b> | I sq. m. 2025    | 16/100        | Kryvyi Rih 62.97, Vinnytsia 62.75, Ternopil 60.35, Lviv 55.61, Kharkiv 54.57     |
| <b>Communities</b>               | II quarter. 2025 | 27/100        | Kryvyi Rih, Dnipro, Ternopil, Uzhhorod, Vinnytsia (points in the range of 68–74) |

Source: Compiled by the authors on the basis of [5; 13].

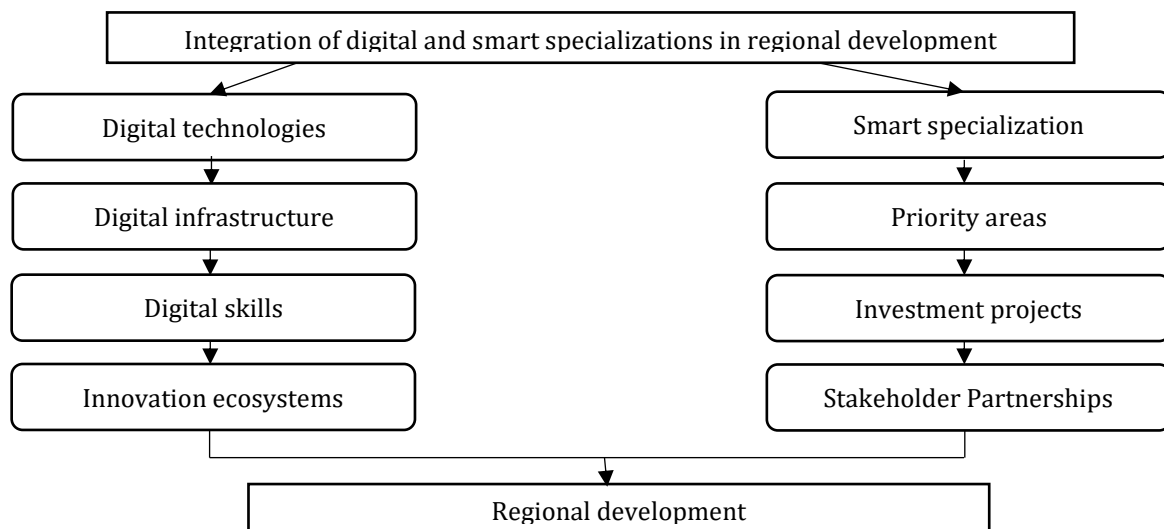
Based on the data in Table. 1, we trace that the value of the Index according to the results of the first quarter of 2025 demonstrated only the initial phase of a systemic breakthrough: the average indicator for the regions was 30 points out of 100 possible, while the leaders were Dnipropetrovsk and Lviv regions (43 points each) and Ternopil region (42 points). At the same time, a number of regions demonstrated a delay in digital growth, which revealed structural unevenness: the digital economy, digital services, the competencies of the population and the readiness of local government for new models of interaction developed at different speeds [13]. Already in the second quarter of 2025, there was a noticeable acceleration: the average index of regions increased to 38 points, and the indicator of communities increased from 16 to 27 points. The group of leaders included Lviv region (54 points), Dnipropetrovsk region (52) and Poltava (50), which demonstrates not only the horizon of progress, but also the emergence of very specific centers of digital modernization. In the segment of communities, the administrative units of Dnipropetrovsk, Ternopil, Vinnytsia, Uzhhorod and Kryvyi Rih regions showed high results, which, unlike more inert territories, have not only integrated digital services into everyday management, but are also trying to form their own electronic development ecosystems [13].

Analyzing the current state of digitalization and the introduction of the concept of smart specialization in Ukraine, it can be stated that this process acquires the characteristics of a multidimensional, systemic and sensitive phenomenon that forms a kind of “digital ecology” of regions. In this environment, not only the availability of technical infrastructure is essential, but also the ability of actors – local communities, enterprises, educational and scientific institutions – to think strategically, interact and make decisions guided by data and analytical models. Regional digitalization is a complex fabric of social, economic and technological interdependencies, where the effectiveness of the implementation of innovation strategies is determined not only by technological capabilities, but also by the depth of adaptation of local communities to their own needs and development potential.

The concept of “digital maturity” acquires a substantive meaning, forming the basis for the transformation of regional economies into competitive and technologically sustainable systems capable of effectively interacting in the global economic environment and ensuring long-term socio-economic growth [2, p. 11].

Digitalization is not only a tool for modernizing administrative processes, but also a fundamental factor in stimulating smart specialization, creating conditions for the comprehensive innovative development of regions. In some territorial communities, a basic digital framework has already been formed, which allows designing new models of economic growth, initiating startups, creating educational and technological clusters integrated into the service economy, as well as increasing the investment attractiveness of regions. At the same time, the process of digital transformation remains uneven: at the level of individual communities and business structures, there are “digital deserts”, where limited access to modern services and a low level of digital competencies potentially hinder the implementation of smart specialization [16].

Such heterogeneity is not perceived as an obstacle, but rather as a resource that allows innovation and financial efforts to be directed where they will have the maximum effect, while stimulating the formation of basic digital infrastructure in less prepared regions.



**Figure 1. Integration of digital technologies and smart specialization in regional development**

Source: Compiled by the authors.

The role of digitalization is of particular importance under martial law, when the destruction of infrastructure, population displacement and socio-economic instability require prompt adaptation and flexible solutions. The presence of even basic digital systems becomes a strategic advantage, providing communication with IDPs, providing online services, creating new forms of employment through remote work and IT services, as well as promptly responding to changes in the economic and social environment. The integration of digital technologies with the smart specialization strategy creates a platform for the formation of sustainable and adaptive economic ecosystems capable of providing intelligent, technological and service directions. The implementation of these scenarios requires a strategic vision, political will, systematic investments in human capital, the development of digital competencies and support from the state and international partners [10, p. 54].

Only under such conditions can regional economic structures be transformed into competitive, flexible and socially inclusive systems capable of effectively responding to dynamic changes and creating new models of the economy focused on sustainable development.

At the same time, it is necessary to take into account deep regional disproportions. The study *Regional Disparities and Economic Growth in Ukraine* indicates that over the past two decades, economic activity, investment, and human capital have been concentrated in a narrow circle of regions, while others have remained on the periphery [9]. This means that even with a common digital policy without taking into account historical, socio-economic and demographic factors, smart specialization risks deepening existing inequalities. Therefore, any approach should be differentiated and contextual: stimulate technology clusters where there is high potential, support basic infrastructure and education where digital resources are limited, while working to develop the skills and competencies of the population.

In general, digitalization, recorded through the Digital Transformation Index of Regions and Communities, indicates the formation of a material and institutional base for the introduction of smart specialization. Combined with the conditions of martial law, this combination of digital technologies, innovative strategies and adaptability can become not only a mechanism for development, but also a means of restoring and rethinking regional strategies. The potential of this integration is realized only if there is political will, strategic investments, international support and equal access of communities to digital resources, which will transform regional economic ecosystems into competitive, flexible and sustainable structures that can effectively adapt to changes and create new economic models.

## 6. Conclusions

From the conducted study, it was found that digitalization and smart specialization in Ukraine are not just separate tools for modernization, but create a holistic, integrated platform for the radical transformation of regional economic ecosystems into competitive, technologically resilient and socially adaptive structures. Digital technologies combined with the smart specialization methodology form a

unique opportunity for the targeted use of local resources, stimulate the development of human capital and create a fertile ground for innovations, startups and technology clusters. In our opinion, artificial intelligence technologies are of particular importance, which can not only automate routine processes, but also create predictable models of economic behavior, assess potential risks, predict the consequences of managerial decisions and increase the transparency of the functioning of regional structures. At the same time, the dynamics of the Digital Transformation Index of Regions and Communities indicates a gradual but uneven growth, which reveals both powerful centers of digital activity and territories with disabilities, which forms the need for a differentiated approach and strategic planning focused on local characteristics, potential, and challenges.

It is important to note that the effective integration of digitalization and smart specialization goes far beyond the technical renewal of infrastructure: it forms a socio-technological mechanism that can ensure not only sustainable economic development, but also social sustainability, adaptation to martial law, and economic diversification of regions. The realization of this potential, directly, requires concerted political will, strategic investments in human capital, the development of digital competencies and the stimulation of innovative initiatives at all levels of government. Only systematic state support, active participation of communities, as well as the targeted use of AI technologies create conditions for the formation of sustainable regional economic ecosystems capable of effectively responding to dynamic changes in the external environment, stimulating high-tech sectors and developing new economic models focused on sustainable development, innovation and social inclusion. In this sense, digitalization and smart specialization cease to be abstract concepts and turn into a practically effective mechanism that can not only fuel economic growth, but also form a new culture of regional development, where digital resources and technologies become an organic component of local strategy and a driving force of transformation processes.

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