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Digitalization of the EU Manufacturing Sector: The Use of Artificial Intelligence

This paper analyzes the statistical toolkit of Eurostat for collecting and processing data on the implementation of Artificial Intelligence (AI) in enterprises across European Union (EU) countries. The study defines the key aspects of evaluating the adoption of AI technologies, such as text mining, natural language generation (NLG), speech and image recognition, machine learning and deep learning, process automation, and autonomous system management. The application of this toolkit allows for the assessment of the digitalization status of the manufacturing sector in the EU and identifies trends in the integration of advanced technologies into business processes.

According to data from 2024, it has been determined that the average level of AI penetration in EU-27 countries remains at an early stage, ranging from 1.46% for autonomous robots to 4.58% for text analysis. It has been analyzed that the most widespread technologies are text mining, NLG, and process automation (RPA/AI software), which can be attributed to their relative ease of implementation and lower investment barriers compared to AI systems embedded in devices, such as autonomous robots for warehouse automation or production assembly works, autonomous drones for production surveillance or parcel handling, etc.

Geographic analysis reveals that the leaders in AI implementation are small to medium-sized economies with a high level of digitalization and developed innovation infrastructure: Luxembourg, Belgium, Denmark, Finland, Austria, the Netherlands, and Sweden. It has been established that text mining and NLG dominate in countries with advanced data analytics, while machine learning and image recognition are more characteristic of high-tech economies in Northern and Western Europe. It has been found that hardware-intensive technologies, such as autonomous robots, are less widespread due to high financial and technical barriers. In particular, a low level of AI adoption is observed in Eastern and Southern Europe, especially in Romania, Greece, Serbia, Cyprus, and Bulgaria. The study underscores the impact of the size and technological development of a country on the level of AI implementation: small, technologically advanced economies show leadership, whereas larger countries with traditional manufacturing sectors exhibit moderate use of these technologies.

In Ukraine from 2026 the government plans to introduce national statistical monitoring of AI usage in enterprises. This will allow for the collection of detailed data on the digitalization of business and the public sector, facilitate the assessment of progress in implementing innovative technologies, monitor strategic priorities, and adjust development policies. Alignment with European standards of AI statistics will ensure comparability of data at the international level and contribute to Ukraine's integration into global economic processes. The introduction of a national statistical toolkit is an important step for monitoring the digital transformation of the economy, assessing the impact of AI on the competitiveness of enterprises and industries, formulating informed strategic decisions, and developing national innovation policy.

Key words: *statistical toolkit, artificial intelligence (AI), digitalization, information and communication technologies (ICT), innovation policy.*

Problem Statement. Digital transformation is one of the key priorities for the development of the European Union (EU). In 2020, President of the European Commission Ursula von der Leyen emphasized the need to ensure digital sovereignty [1]. In 2021, the European Commission introduced the "Digital Compass for the EU's Digital Decade" (hereinafter referred to as the "Digital Compass"), aimed at defining the EU's digital transformation strategy through 2030 [2]. This initiative focuses on developing potential across four strategic areas: digital skills – enhancing digital literacy and citizens' competencies; infrastructure – developing high-speed internet, cloud services, and quantum technologies; business and public services – supporting the digitalization of enterprises and the public sector; digital governance and security – strengthening cybersecurity, implementing digital identifiers, and developing data policies.

It should be noted that the measures of the EU's current digital policy are based on the provisions of the 2015 Digital Single Market Strategy [3], which aimed to create an integrated digital space, promote cross-border e-commerce, scale digital services, foster innovation, and modernize digital infrastructure. The strategy's implementation is expected to enhance business competitiveness and efficiency, particularly for small and medium-sized enterprises (SMEs), and contribute to GDP growth. The adoption of EU strategic documents has provided a strong impetus for the development of information and communication technologies (ICT), including artificial intelligence (AI) technologies, within manufacturing enterprises.

This momentum was further supported by the adoption of the 2021–2027 Digital Europe Programme, with a budget of approximately €7.5 billion [4]. The programme aims to accelerate the digital transformation of the EU economy, society, and public sector. Key funding priorities include: supercomputing/high-performance computing – approximately €2.23 billion; AI – approximately €2.06 billion; cybersecurity and trust – approximately €1.65 billion; advanced digital skills – approximately €577 million; deployment of digital technologies and interoperability – approximately €1.07 billion. The Digital Europe Programme seeks to reduce the gap between scientific research and the commercial application of technologies, creating favorable conditions for innovation in both business and the public sector, particularly for SMEs. AI, alongside other ICTs, is expected to accelerate innovative development and bring Europe closer to technological sovereignty. Several important policy decisions have been adopted to formalize this process [5; 6].

These developments over the past decade in the EU are highly relevant for Ukraine, which, pursuing a European integration path, gradually implements EU approaches in digital economy development, including AI [7]. In the national context, the Strategy for Digital Development of Innovative Activities in Ukraine until 2030, adopted by the Government, is of key importance. It aims to create conditions for the implementation and practical application of high-tech products, particularly those based on AI technologies [8]. Successful implementation of the measures outlined in this strategy's operational plan will enable Ukraine to establish a competitive innovation ecosystem, fostering productivity growth, investment attraction, knowledge and technology development, and integration into the European research space.

In this context, it is important to consider the EU's experience in assessing the level of digitalization of the economy and its socio-economic impacts. Analysis of Eurostat's statistical instruments allows for the identification of methodological principles for forming an effective system to measure innovation development based on ICT. Such a system is a prerequisite for strategic planning and monitoring of digital transformation in Ukraine, as well as for evaluating the effectiveness of implemented measures in digitalization and AI technology development.

Analysis of Recent Research and Publications. To identify current trends in the digitalization of the economy, recent scholarly works analyzing the implementation of AI technologies and assessing their economic impacts using statistical methods were reviewed.

D. Nepelski & M. Sobolewski [9], in a study published by the European Commission's Joint Research Centre (JRC), highlight the issue of incomplete and fragmented data on AI investments, which complicates the assessment of their effect on economic transformation. The authors proposed a comprehensive methodology combining a top-down approach with AI-intensity coefficients, enabling the estimation of the share of investments directly associated with AI development. Their approach involves disaggregating macroeconomic data (e.g., IT personnel costs, R&D expenditure, intangible assets) according to the portion related to AI. For instance, if 10% of all R&D patents pertain to AI, then the corresponding share of R&D investments is attributed to AI. This methodology allows for the assessment of investment magnitude based on AI usage intensity across sectors rather than relying solely on accounting data. Using Eurostat, Spintan, and Intan-Invest databases, the authors classified investments into three categories: talents, skills, and lifelong learning (ICT personnel remuneration, training, education); from lab to market (organizational capital, brand, design); and data, technology, and infrastructure (equipment, software, databases, R&D). Their estimates indicated that total AI investments in the EU in 2018 amounted to approximately €1.948 trillion, or 12.3% of GDP, highlighting the significant role of human capital, research, and innovation. At the same time, substantial heterogeneity across EU countries underscores the need to harmonize statistical approaches.

Fonteneau et al. [10] further developed this methodology, proposing a two-step approach for assessing AI investments. In the first step, they aggregated macroeconomic data across major investment categories; in the second, they applied AI-intensity coefficients calculated based on the shares of AI-related patents, scientific publications, educational programs, and ICT specialists. The study drew upon data from Eurostat, EUKLEMS, INTANProd, StudyPortals, UNESCO WHED, and

OECD PATSTAT. Investments were categorized into four groups: skills, R&D, data and equipment, and intellectual property. Their estimates suggest that in 2023, total AI investments in the EU-27 amounted to €220–294 billion (base estimate €257 billion), with over 70% originating from the private sector. The largest shares were allocated to skills (40.97%) and data and equipment (37.11%). Germany, France, and the Netherlands were the leading investors, whereas the United States demonstrated the highest global investment in AI research.

F. Calvino & L. Fontanelli [11] applied a distributed microdata approach to assess AI adoption at the enterprise level across 11 OECD countries. Their results indicate that AI is most extensively utilized by large firms with advanced ICT infrastructure and access to data. Subsequent studies (F. Calvino & L. Fontanelli, 2024; D. Czarnitzki et al., 2023) [12; 13] confirmed the positive impact of AI intensity on firm productivity, business model innovation, and managerial efficiency.

C. M. Ionașcu [14] employed k-means clustering and principal component analysis (PCA) to classify EU countries based on the level and dynamics of AI adoption from 2021 to 2024. Findings reveal that despite overall growth in AI implementation, disparities among countries persist, with key barriers including skill shortages, high costs, and regulatory uncertainty. This underscores the need to develop a harmonized AI statistical framework to support effective digital policy.

Overall, the review demonstrates that contemporary research – both at the macroeconomic level (AI investment assessment) and microeconomic level (enterprise-level AI adoption analysis) – shows significant progress. However, limitations persist due to fragmented and asymmetric data across countries. This highlights the importance of further improving statistical tools for measuring digitalization processes and AI technology implementation.

The development of reliable, standardized, and comparable statistics on AI deployment is essential for conducting robust research on ICT adoption trends, particularly AI, in business processes. Moreover, such statistics are integral to formulating evidence-based policies for digital economic transformation and evaluating the effectiveness of implemented measures.

In Ukraine, the issue of economic digitalization has also been widely addressed in scholarly literature [15]. In the study by Y. Bazhala [16], it is emphasized that digitalization represents a key component of the contemporary technological paradigm, acting both as a driving force and a consequence of structural changes in the economy. The author conceptualizes digital transformation as an integral element of technological renewal, influencing productivity, innovation activity, and human capital development.

S. Bashlay and I. Yaremko [17] examine the digitalization of Ukraine's economy within the context of European integration processes. They argue that, despite martial law, digital transformation in Ukraine continues and is becoming increasingly critical. The study highlights the need for investment in digital platforms and identifies key areas of business management, including collaboration and convergence, cybersecurity, digital competence, and the development of digital skills.

D. Kotelevets [18] analyzes trends in the development of the digital economy in Ukraine, noting that enterprise competitiveness in a digital environment is determined by the ability to rapidly implement information technologies, generate digital products, and respond swiftly to changes in demand. The author considers digital adaptability a strategic resource for national economic growth.

P. Zub & H. Kalach [19] focus on the digitalization of business processes in industrial enterprises. They systematize methodological foundations for enterprise digitalization based on information systems concepts, identify the key areas influenced by digitalization – customer interaction, value proposition, and internal infrastructure management – and outline the main components of an integrated information environment for automating production processes.

Collectively, these and other studies [20; 21] confirm the strategic importance of digital transformation, particularly the adoption of AI, as a prerequisite for economic modernization and integration into global value chains. They illuminate organizational, managerial, and infrastructural aspects of digital development at both the enterprise and national economy levels. However, they often overlook the statistical tools necessary to assess the scale of digital transformation. The absence of a harmonized system of indicators, measurement methodologies, and integrated data models limits the ability to conduct objective empirical analyses of progress in Ukraine's digital and high-tech sectors.

The aim of this article is to analyze Eurostat's statistical toolkit for collecting data on the use of digital technologies, including AI, in EU enterprises, and to perform an economic-statistical assessment of digitalization trends in the manufacturing sector.

Research Results and Discussion. The adoption of strategic documents by the European Union on digitalization represents not only a political step but also a response to profound technological shifts in the economy. Consequently, there has arisen a need to establish a reliable statistical framework to assess the level of implementation of information and communication technologies (ICT) in both manufacturing and service sectors, as well as to monitor their impact on enterprise-level economic indicators [22].

Eurostat has introduced a dedicated statistical domain – digitalization statistics – providing data on the implementation and use of ICT [23], including e-commerce, cloud technologies, data analytics, and artificial intelligence (AI) [24]. Since 2002, Eurostat has conducted annual surveys on ICT usage by enterprises [25]. Initially, these surveys focused on general aspects such as Internet use, business process computerization, and participation in e-commerce, forming corresponding datasets [26].

In 2020, Eurostat, in collaboration with the OECD, gradually incorporated survey questions regarding enterprise adoption of AI technologies. This initiative was part of the harmonization process for statistical tools aimed at tracking the diffusion of advanced digital technologies, as AI is increasingly integrated into business processes, from data analytics and production automation to logistics and customer service management. Initially, AI-related questions were piloted to test their clarity and applicability. Starting from 2023, they were fully integrated into the standard survey, enabling systematic measurement of AI implementation at the enterprise level.

To standardize methodology across EU member states, ensure data comparability, and define common approaches for compilation, validation, and dissemination of AI-related statistics, Eurostat provides detailed methodological guidance in the European Business Statistics Handbook on ICT usage in enterprises [27]. The data collection and processing workflow comprises four main stages: compilation of national data, submission to Eurostat, quality assessment and validation, and publication in open access.

In the Handbook, particularly in Module E, AI is defined as systems employing technologies such as text analytics, computer vision, speech recognition, natural language generation, machine learning, and deep learning to collect and/or utilize data for forecasting, recommendation generation, or decision-making – with varying degrees of autonomy – to achieve specific objectives. AI systems may be:

- purely software-based, e.g., chatbots, business assistants using natural language processing, facial or speech recognition systems, machine translation software, and machine learning-based analytical tools;
- embedded in devices, e.g., autonomous robots for production automation, drones for monitoring or cargo handling [27].

Module E, "Artificial Intelligence," contains seven blocks of questions covering key AI technologies and their business applications. Analysis of questions E1–E7 allows a comprehensive assessment of AI adoption at enterprises, identification of practical application areas, technological autonomy, ethical and legal aspects of AI usage, as well as barriers hindering digital transformation. The module's structure ensures a logical progression of data collection – from confirming the presence of technologies to analyzing objectives, data acquisition methods, use of personal data, and ethical compliance. This approach enables Eurostat and national statistical authorities to produce cross-country comparable data, forming the basis for monitoring the digital economy and evaluating policies supporting AI adoption.

Question E1 (Table 1, adapted from [27]) aims to determine which technologies enterprises deploy, for what purposes (automation, analytics, customer support, production management, etc.), and in which areas the greatest growth potential is observed. These technologies enable enterprises to automate routine operations, enhance decision-making accuracy, utilize data more efficiently, improve customer interactions, and create innovative products and services.

Table 1

Question E1: Use of AI Technologies

AI Technology	Example Applications	Description
a) Text Mining	Social media analysis, business analytics, risk management, chatbots, contextual advertising, spam filtering	Conversion of unstructured text into structured information for analysis and decision-making
b) Speech Recognition	Call centers, digital assistants (Siri, Alexa, Google Voice)	Conversion of spoken language into text to automate voice data processing
c) Natural Language Generation (NLG) / Speech Synthesis	Chatbots, automated reports, technical manuals, product descriptions, news articles	Generation of text or speech based on data; automates communication processes
d) Object / Face Recognition in Images or Video	Biometric identification, quality control, autonomous vehicles, drones	Computer vision for image and video analysis; process monitoring and safety control
e) Machine and Deep Learning	Recommendation systems, dynamic pricing, cyber threat detection	Training models to automate tasks and perform predictive analytics
f) AI-based Robotic Process Automation (RPA)	Chatbots, web crawlers, automation of repetitive tasks	AI supports or fully automates business processes
g) Autonomous Physical Motion	Autonomous robots, delivery drones, self-driving vehicles	AI governs the movement of machines based on environmental analysis

Questions E2 (Table 2, compiled based on [27]) aim to identify the main purposes of AI deployment within enterprises and the level of integration of these technologies into business processes. These questions allow researchers to determine why companies implement AI – whether for process optimization, management, security, or innovation development. AI technologies support enterprises in automating marketing, sales, and production processes, optimizing logistics and resource management, ensuring IT security and financial control, and creating new products and innovative solutions.

Table 2

Question E2: Purposes of AI Use

Purpose of AI Use	Example Applications	Description
a) Marketing or Sales	Customer profiling, personalized offers, chatbots, autonomous order-handling robots	Automation of customer interaction and enhancement of sales efficiency
b) Production or Service Processes	Predictive maintenance, product classification, autonomous drones	Optimization of production processes, quality improvement, and safety enhancement
c) Business Process Management	Virtual assistants, HR analytics, business forecasting	Support for managerial decision-making and planning
d) Logistics	Route optimization, inventory management, packing robots	Improvement of transportation and storage efficiency
e) IT Security	Biometric authentication, cyber threat detection	Use of AI to protect information systems
f) Accounting, Controlling, or Finance	Automated bookkeeping, fraud detection, financial analytics	Ensuring control and accuracy of financial operations
g) R&D or Innovation	Data analysis, development of new products	Application of AI for research and development purposes

Questions E3 (Table 3, compiled based on [27]) investigate how enterprises acquire or develop AI solutions, reflecting their level of technological autonomy and innovative capacity. This section allows for assessing whether enterprises possess in-house resources to develop AI systems, the role of external providers in the creation or implementation of AI solutions, and the degree of reliance on commercial or open-source software.

Questions E4 (Table 4, compiled based on [27]) are aimed at determining whether enterprises use AI for the analysis or processing of personal data of customers, employees, or candidates. This allows for identifying the volume and categories of personal data being processed, assessing the level of technological integration of AI in HR, marketing, or analytics, and revealing potential privacy risks and ethical considerations.

Table 3

Question E3: How Enterprises Obtain AI Software or Systems

Acquisition Method	Example Applications	Description
a) Developed In-House	Sales forecasting algorithms, internal chatbots	AI development is carried out entirely by the enterprise's own staff
b) Commercial Software Modified In-House	Purchased software adapted to company needs	Use of ready-made solutions with internal customizations
c) Open-Source Software Modified In-House	Open-source solutions adapted for business-specific requirements	Combination of open-source technologies and internal expertise
d) Purchased Commercial Software	Cybersecurity or data analytics software	Off-the-shelf solutions used without modification
e) Developed by External Providers	Chatbots or analytics systems created by an external company	Outsourcing AI development to third-party provider

Table 4

Question E4: Processing of Personal Data Using AI

Question	Examples	Explanation
E4: Does the enterprise process personal data using AI? (Yes/No)	Data on customers or employees: age, gender, ethnic origin, facial images, purchases, performance evaluation	AI is used for analysis or profiling in marketing, HR, and performance management

Question E5 (Table 5, compiled from [27]) aims to determine whether enterprises monitor the fairness of AI outcomes. This section allows for the identification of procedures for ethical auditing of algorithms, assessment of trust in automated decisions, and the prevention of discrimination in AI-based decision-making.

Question E6 (Table 6, adapted from [27]) assesses whether the organization has considered the possibility of implementing AI if it is not currently in use. These questions allow for: evaluating the company's innovation potential, determining the level of awareness regarding the benefits of AI, and segmenting organizations based on their readiness for digital transformation.

Table 5

Question E5: Checking AI Outputs for Bias

Question	Examples of Measures	Explanation
E5: Does the organization have measures in place to check AI outputs for bias? (Yes/No)	Model audits, data representativeness testing, use of synthetic data, model monitoring, team diversification	The goal is to prevent discrimination based on gender, age, race, religion, or disability

Table 6

Question E6: Consideration of AI Implementation

Question	Examples	Explanation
E6: Has the organization considered using AI if it is not currently implemented? (Yes/No)	Potential applications for sales forecasting, customer service, logistics optimization	Identifies organizations planning to implement AI in the future

Question E7 (Table 7, adapted from [27]) investigates the barriers that prevent organizations from implementing AI, even when there is interest. This section helps to: identify key constraints on business technological development, assess economic, legal, and ethical factors, and formulate directions for government support of digitalization.

Table 7

Question E7: Reasons for Not Using AI

Reason	Examples	Explanation
a) High costs	Software expenses, staff training, integration	Costs exceed the expected benefits
b) Lack of expertise	Absence of specialists, management complexity	Insufficient technical competence
c) Incompatibility with systems	Legacy infrastructure, technical limitations	Need for system modernization
d) Data issues	Lack of quality or structured data	Inability to train models
e) Privacy and data protection	Concerns over GDPR compliance	Risks of data leaks or discrimination
f) Legal uncertainty	Lack of regulation, legal risks	Unclear liability for AI actions
g) Ethical considerations	Transparency, fairness, non-discrimination	Adherence to principles of ethical AI use
h) No perceived need	Business specifics do not require automation	AI does not create additional value for the organization

Thus, the questions included in Module E of the statistical survey of enterprises in EU countries form the methodological basis for further analysis of AI technology implementation in industry. The statistical offices of EU member states have implemented the recommendations provided by Eurostat regarding AI data collection in their statistical observations. Eurostat also collects data for Turkey, even though the country is not an EU member, as it participates in the EU's extended statistical cooperation system – the European Statistical System (ESS) – as a partner country. This ensures the comparability of indicators and allows for the analysis of digitalization processes not only within the EU-27 but also in countries integrating into the European economic area.

It should be noted that in July 2025, a new European Commission Regulation 2025/1310 [28] was adopted, establishing technical specifications for data requirements as well as schedules for the submission of annual metadata and quality reports on the topic "Use of ICT and E-commerce," in accordance with the framework Regulation (EU) 2019/2152 [29]. The document defines an updated structure for statistical data collection for reporting in 2026, including an expanded module dedicated to the use of AI technologies in enterprises of EU member states. The regulation details the list of mandatory variables, covering the main areas of AI application in business. Particular attention is given to ethical issues and algorithmic bias. For enterprises using AI in the processing of personal data, mandatory reporting is required on the existence of measures to check for potential discriminatory effects of machine learning models – for example, dataset analysis, model testing, and the use of synthetic data. Requirements have also been established for collecting information on the barriers to AI implementation among enterprises that have not yet adopted such technologies.

Based on official Eurostat data for 2024 [23; 25], an economic-statistical study was conducted aimed at: evaluating the extent of the use of specific AI technologies by manufacturing enterprises in the EU-27 countries; identifying territorial differences in the level of industrial digitalization; determining leading and lagging countries in key areas of AI application; and analyzing the structure of technology use by type – software-based and hardware-based solutions.

To achieve this objective, a series of graphical representations (Figures 1–7, constructed using data from [23; 26]; hereinafter EU27 (from 2020)) was created, illustrating the share of enterprises implementing various AI technologies: text mining, speech recognition, natural language generation (NLG), image recognition, machine learning, AI-based robotic process automation (RPA), as well as autonomous systems (autonomous robots, self-driving vehicles, drones). The obtained statistical indicators form the basis for a comparative analysis of the level of industrial digitalization in EU countries, enabling the identification of patterns in innovation diffusion and the determination of strategic benchmarks for Ukraine in the context of its European integration course and the development of national AI policy.

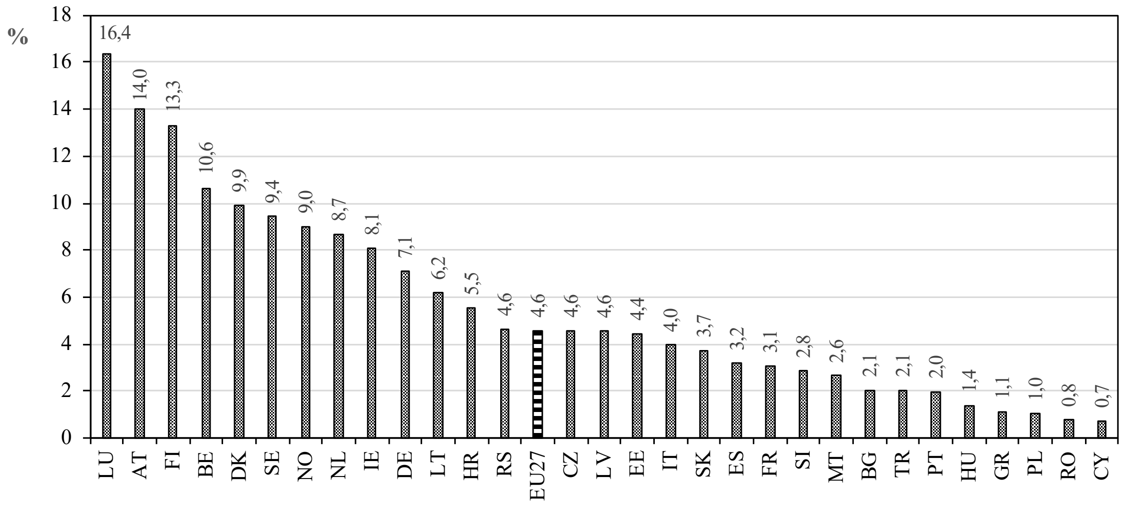

Figure 1. Use of AI technologies by manufacturing enterprises for text mining, 2024, % of enterprises

Note: Hereinafter Austria (AT), Belgium (BE), Bulgaria (BG), Cyprus (CY), Czech Republic (CZ), Germany (DE), Denmark (DK), Estonia (EE), Spain (ES), Finland (FI), France (FR), Greece (GR), Croatia (HR), Hungary (HU), Ireland (IE), Italy (IT), Lithuania (LT), Luxembourg (LU), Latvia (LV), Malta (MT), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Serbia (RS), Sweden (SE), Slovenia (SI), Slovakia (SK), Turkey (TR).

According to Figure 1, on average, 4.58% of manufacturing enterprises in the EU-27 use AI technologies for text mining. The highest shares are observed in Luxembourg (16.38%), Austria (14.03%), Finland (13.28%), and Belgium (10.64%), indicating a high level of digitalization and well-developed analytical infrastructure in these small but highly technologically advanced economies. In contrast, the lowest values are recorded in Cyprus (0.72%), Greece (1.11%), Hungary (1.37%), and Poland (1.02%), which may reflect a lower level of industrial digitalization and limited resources for implementing big data analytics technologies. Thus, territorial differences in the use of text mining in industry are clearly evident: leading countries are concentrated in Central and Northern Europe, while countries with the lowest levels of adoption are mostly located in Southern and Eastern Europe. This pattern highlights the relationship between technological development, the scale of industrial production, and investments in digitalization.

According to Figure 2, on average, 2.94% of manufacturing enterprises in the EU-27 use AI technologies for speech recognition. The highest shares are recorded in Luxembourg (9.51%), Finland (6.09%), Belgium (6.32%), Denmark (5.86%), and Germany (5.99%), reflecting a high level of office and production process automation, as well as active development of research and innovation activities in these countries.

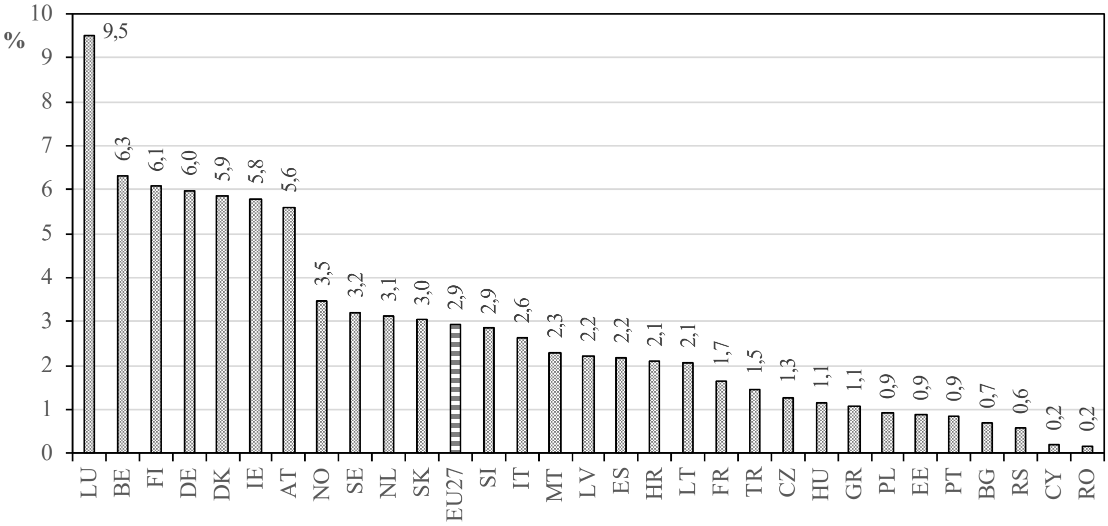

Figure 2. Use of AI technologies by manufacturing enterprises for speech recognition, 2024, % of enterprises

In contrast, the lowest values are observed in Romania (0.17%), Cyprus (0.19%), Bulgaria (0.69%), and Hungary (1.14%), indicating limited digital resources and relatively low demand for the implementation of speech recognition in industrial processes. Thus, territorial differences in the use of speech recognition clearly correlate with the level of digitalization and automation of enterprises: the leaders are countries in Northern and Western Europe with well-developed innovation infrastructure, while the lagging countries are those with lower technological development and fewer investments in digital solutions.

According to Figure 3, on average, 3.53% of manufacturing enterprises in the EU-27 use AI technologies for generating written or spoken language (Natural Language Generation, NLG). The highest levels of adoption are observed in Belgium (12.28%), Denmark (12.06%), Finland (12.02%), Austria (9.14%), and Luxembourg (8.28%), indicating active development of data analytics and text processing capabilities in these countries. In contrast, the lowest values are recorded in Cyprus (0.17%), Serbia (0.29%), Romania (0.47%), and Greece (1.37%), reflecting limited digital resources and lower readiness of enterprises to implement innovative software solutions. Thus, the diffusion of NLG in the EU manufacturing sector is characterized by significant territorial differentiation: leading countries are those with a high level of digitalization and well-developed analytical data processing infrastructure, while lagging countries are primarily located in Southern and Eastern Europe.

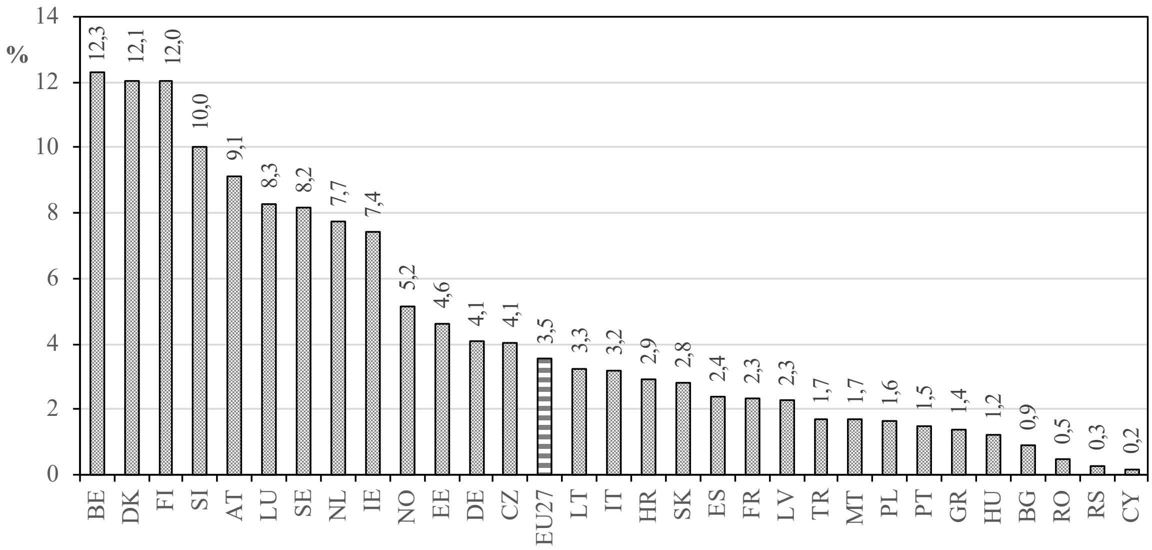

Figure 3. Use of AI technologies by manufacturing enterprises for natural language generation (NLG), 2024, % of enterprises

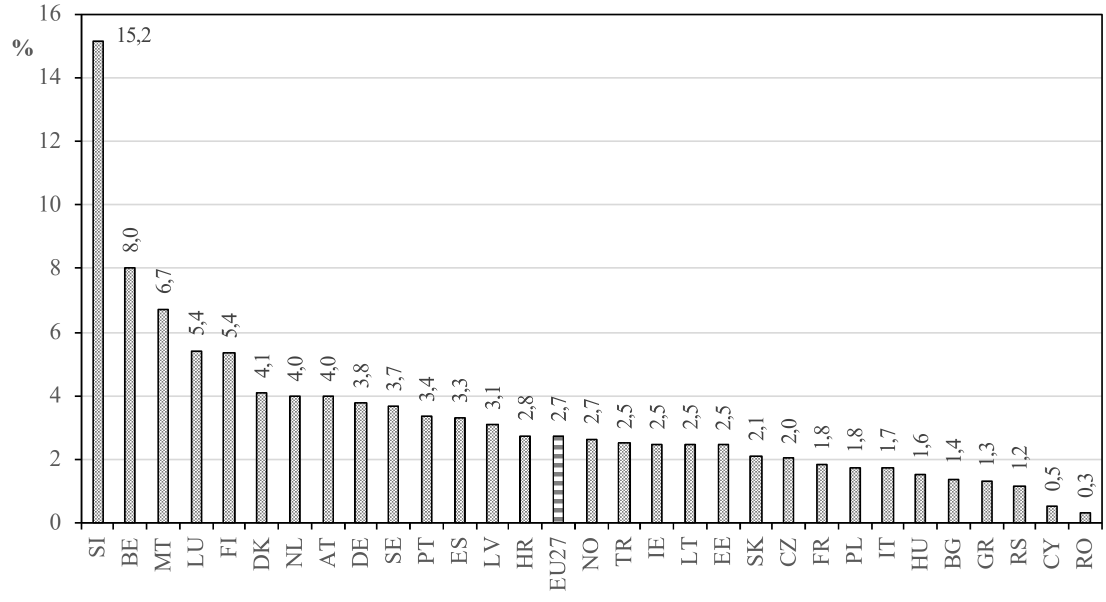

Figure 4. Use of AI technologies by manufacturing enterprises for image recognition and processing, 2024, % of enterprises

According to Figure 4, on average, 2.74% of manufacturing enterprises in the EU-27 use AI technologies for identifying objects or individuals based on images (image recognition, image processing). The highest adoption levels are observed in Slovenia (15.17%), Belgium (8.03%), Malta (6.74%), Luxembourg (5.42%), and Finland (5.35%), indicating active implementation of high-tech production solutions in small and medium-sized economies with a developed technological sector. The lowest values are recorded in Romania (0.32%), Cyprus (0.53%), and Greece (1.30%), reflecting limited access to digital technologies and insufficient infrastructure for image processing in industry. Thus, the use of AI for image processing in the EU manufacturing sector exhibits territorial unevenness: leading countries are those with high-tech manufacturing and innovation infrastructure, while countries with low adoption levels are predominantly located in Eastern and Southern Europe.

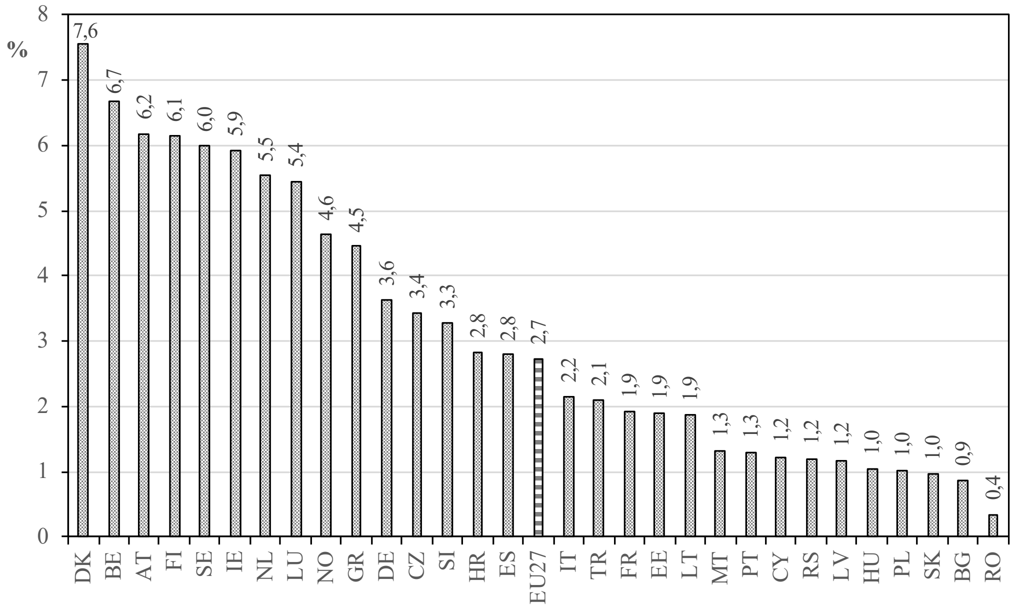

Figure 5. Use of machine learning (e.g., deep learning) by manufacturing enterprises for data analysis, 2024, % of enterprises

According to Figure 5, on average, 2.73% of manufacturing enterprises in the EU-27 use machine learning for data analysis. The highest adoption levels are observed in Denmark (7.55%), Belgium (6.67%), Finland (6.14%), Austria (6.18%), and Ireland (5.92%), indicating a concentration of analytical tool usage in countries with a well-developed analytical culture and high levels of enterprise innovation. The lowest values are recorded in Romania (0.35%), Poland (1.01%), and Slovakia (0.96%), reflecting limited digitalization and relatively low development of innovative practices in Eastern European industry. Thus, the use of machine learning in the EU-27 manufacturing sector exhibits territorial unevenness, with leading countries in Northern and Western Europe and lagging adoption characteristic of Eastern Europe.

According to Figure 6, on average, 3.23% of manufacturing enterprises in the EU-27 use AI for workflow automation (RPA/AI software). The highest adoption levels are observed in Belgium (9.46%), Luxembourg (7.67%), Finland (6.94%), Denmark (6.94%), and Sweden (6.38%), reflecting a high level of business process automation and active use of software solutions to improve production efficiency. The lowest values are recorded in Romania (0.52%), Serbia (1.00%), and Greece (1.21%), indicating limited digitalization and lower innovation activity in enterprises in Southern and Eastern Europe. Thus, the implementation of workflow automation demonstrates territorial unevenness, with leaders in Northern and Western Europe having developed infrastructure and high digital capacity, while lagging adoption is characteristic of Southern and Eastern Europe.

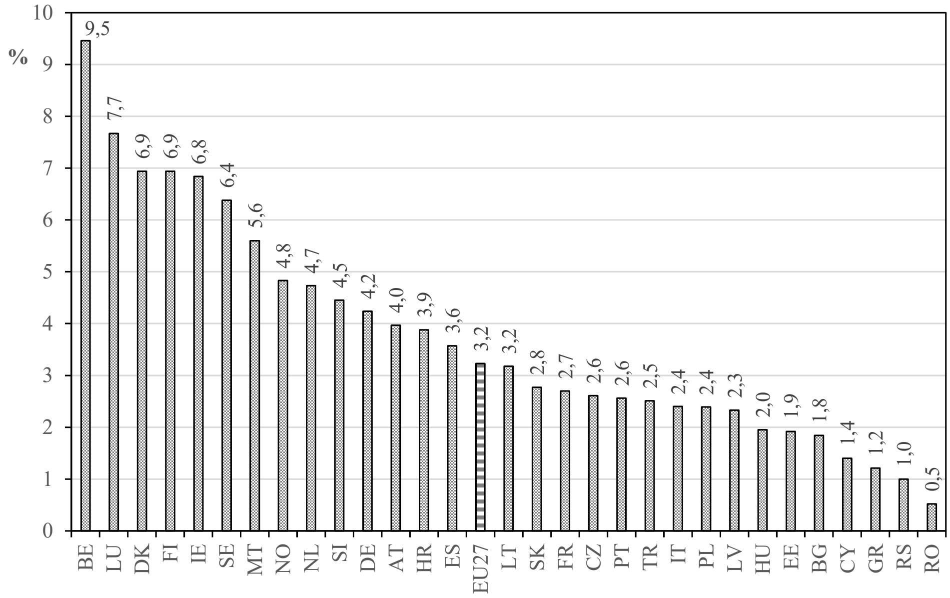

Figure 6. Use of AI technologies by manufacturing enterprises for automating various workflows or supporting decision-making (AI-based software robotic process automation), 2024, % of enterprises

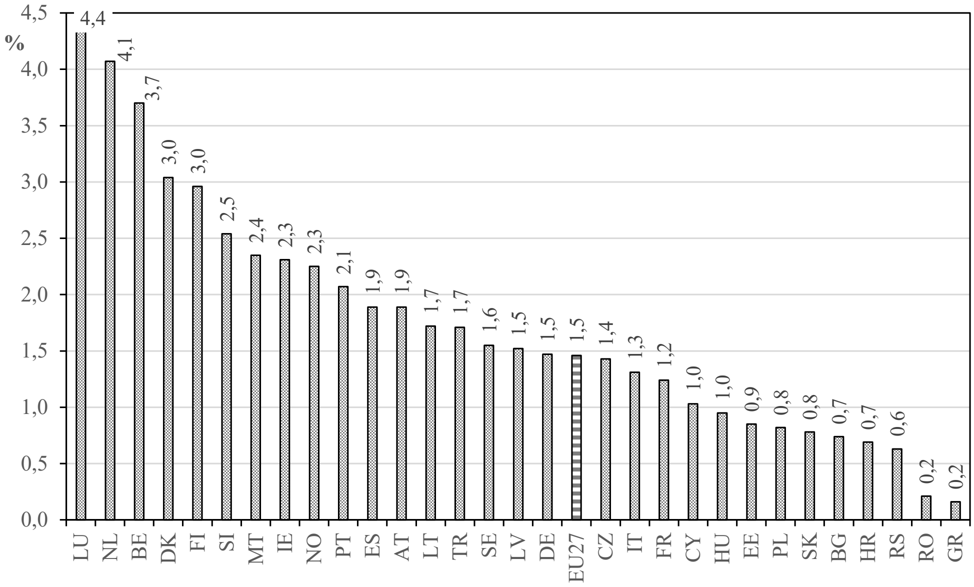

Figure 7. Use of AI technologies by manufacturing enterprises for enabling physical movement of machines through autonomous solutions based on environmental observation (autonomous robots, self-driving vehicles, autonomous drones), % of enterprises

According to Figure 7, on average, 1.46% of manufacturing enterprises in the EU-27 employ autonomous robots and vehicles. The highest adoption levels are observed in Luxembourg (4.36%), the Netherlands (4.07%), Slovenia (2.54%), Finland (2.96%), and Denmark (3.04%), reflecting a high level of innovation and technological maturity in smaller economies. The lowest values are recorded in Greece (0.16%), Romania (0.21%), and Croatia (0.69%), which can be attributed to the significant costs of high-tech equipment and the complex infrastructure required for integrating autonomous systems. Thus, the use of autonomous robots and vehicles demonstrates territorial unevenness, with leaders being economies with high innovation capacity, while lagging adoption is characteristic of Southern and Eastern Europe, indicating the need for additional investment in technological infrastructure and digitalization.

Based on an analysis of AI technology adoption in manufacturing across the EU-27 (2024 data), the following conclusions can be drawn.

The overall level of AI adoption, measured by the average deployment of autonomous robots in manufacturing enterprises within the EU-27, stands at 1.46%, while text analysis (text mining) reaches 4.58%. This indicates that AI integration in manufacturing is still in its early stages, even in highly developed countries. The most commonly implemented AI technologies are text analysis, natural language generation (NLG), and process automation (RPA/AI software), with average adoption rates across the EU-27 ranging from 3% to 4.5%. The popularity of these technologies can be explained by their relative ease of implementation and lower investment barriers compared to hardware-intensive systems. Leading countries – Luxembourg, Belgium, Denmark, Finland, Austria, the Netherlands, and Sweden – are small or medium-sized economies with high levels of technological development, active digitalization, and strong innovative infrastructure.

Text mining and NLG are widespread in countries with advanced data analytics capabilities, whereas machine learning and image recognition are more common in high-tech countries in Northern and Western Europe. Technologies that are less widespread include autonomous robots and other hardware-intensive systems (1.46%).

Low adoption rates in Eastern and Southern Europe (Romania, Greece, Serbia, Cyprus, Bulgaria) are due to limited financial resources, lower levels of digitalization, and reduced innovation activity. A country's size and technological development have a significant impact on AI adoption: small, technologically advanced countries tend to lead, while large economies with traditional industries show moderate adoption. Software-oriented solutions (text mining, NLG, ML) are prevalent in countries with significant investments in analytics, while hardware-oriented solutions (RPA, autonomous robots) are found in countries with strong robotics and automation capabilities.

The analysis also highlights a geographic divide: Northern and Western Europe are actively integrating AI, while Southern and Eastern Europe lag behind due to lower digitalization, limited investments, and a shortage of skilled personnel. Software solutions remain the most popular, while hardware-intensive technologies are developing more slowly due to high investment barriers.

Overall trends suggest that leaders in AI adoption will focus on process automation and data analytics, while hardware-intensive solutions will evolve more slowly due to the significant investment required.

Conclusions. The study has shown that the development of Eurostat's statistical tools for analyzing the implementation of AI in the EU business sector is an important component of the systematic monitoring of digital transformation and the realization of the Industry 4.0 concept. Eurostat's reliable statistical base enables the assessment of the scale of digital transformation, the measurement of the impact of emerging technologies on the competitiveness of enterprises and the economy as a whole, as well as the use of these data for effective strategic planning and investment in the development of digital technologies.

For Ukraine, which aims to integrate into the European digital space, the collection and analysis of ICT statistical data is crucial for the development and adjustment of the national digital strategy. This data will help assess the level of access to ICT, the effectiveness of technology implementation in business and the public sector, as well as the level of digital literacy of the population. An important part of this process is the use of international standards and comparative indicators, which allow for tracking progress and facilitating Ukraine's alignment with European standards of information society development. In this context, active participation in Eurostat initiatives and the use of statistical data to monitor the digital divide is an important step towards improving the country's digital infrastructure. A significant step for Ukraine is the introduction of national statistical tools similar to European practices. In this regard, starting in 2026, the State Statistics Service of Ukraine plans to initiate a state statistical observation of AI usage in enterprises [28]. This will allow for the collection of detailed data on the implementation of AI technologies in business, which is essential for the development of ICT and e-commerce.

Orientation towards European standards in AI statistics, particularly Regulation (EU) 2019/2152 [29] and Regulation (EU) 2025/1310 [30], will ensure data comparability at the international level and facilitate Ukraine's integration into global economic processes. The implementation of statistical tools for monitoring AI adoption at the national level will enable the assessment of the progress of digitalization in the economy and industrial sectors, as well as the adjustment of innovation development policies in Ukraine.

These changes represent a promising direction for further research, which will help form more effective policies for digital transformation at both the state and enterprise levels. Going forward, it is important to continue improving the methodology for data collection and ensuring the high quality of statistics to monitor the implementation of emerging technologies across all sectors of the economy and society.

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Цифровізація промисловості ЄС: використання штучного інтелекту

У статті проаналізовано статистичний інструментарій Євростату для збирання й обробки даних щодо впровадження штучного інтелекту (ШІ) на підприємствах країн Європейського Союзу. Визначено основні аспекти оцінки рівня використання технологій ШІ, таких як аналіз тексту (text mining), генерація природної мови (NLG), розпізнавання мовлення та зображень, машинне та глибинне навчання, автоматизація процесів і автономне керування системами. Застосування цього інструментарію дозволяє встановити стан цифровізації промислового сектору ЄС та виявити тенденції інтеграції передових технологій у бізнес-процеси. За даними 2024 року визначено, що у країнах ЄС-27 середній рівень проникнення ШІ залишається на початковому етапі: від 1,46% для автономних роботів до 4,58% для аналізу письмового тексту. Обґрунтовано, що найпоширенішими технологіями є text mining, NLG та автоматизація процесів (RPA/AI software), що пояснюється відносною простотою їхнього впровадження та нижчими інвестиційними бар'єрами порівняно з вбудованими системами, представленими автономними роботами для автоматизації складів і виробничих процесів, а також дронами, що виконують спостереження або обробку вантажів.

Географічний аналіз показав, що лідерами впровадження ШІ є невеликі або середні за розміром економіки з високим рівнем цифровізації та розвиненою інноваційною інфраструктурою: Люксембург, Бельгія, Данія, Фінляндія, Австрія, Нідерланди та Швеція. Встановлено, що text mining і NLG переважають у країнах із розвиненою аналітикою даних, тоді як машинне навчання та розпізнавання зображень характерні для високотехнологічних економік Північної та Західної Європи. Виявлено, що менш поширеними є hardware-intensive технології, зокрема автономні роботи, через високі фінансові та технічні бар'єри. Зокрема, низький рівень використання ШІ спостерігається у Східній та Південній Європі, насамперед у Румунії, Греції, Сербії, Кіпрі та Болгарії. Дослідження обґрунтовує вплив розміру та технологічного розвитку країни на рівень упровадження ШІ: маленькі технологічно розвинені економіки демонструють лідерство, тоді як великі країни з традиційною промисловістю мають помірне використання технологій.

В Україні з 2026 року планується запровадження державного статистичного спостереження за використанням ШІ на підприємствах. Це дозволить отримати детальні дані щодо цифровізації бізнесу та державного сектору, сприятиме оцінці прогресу впровадження інноваційних технологій, моніторингу стратегічних пріоритетів і коригуванню політики розвитку. Орієнтація на європейські стандарти статистики ШІ дозволить досягти порівнянності даних на міжнародному рівні та сприятиме інтеграції України у глобальні економічні процеси. Запровадження національного статистичного інструментарію є важливим кроком для моніторингу цифрової трансформації економіки, оцінки впливу ШІ на конкурентоспроможність підприємств і галузей, формування обґрунтованих стратегічних рішень та розвитку національної політики у сфері інновацій.

Ключові слова: *статистичний інструментарій, штучний інтелект (ШІ), цифровізація, інформаційно-комунікаційні технології (ІКТ), інноваційна політика.*

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