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## KEY DETERMINANTS OF THE GROWING IMPORTANCE OF DIGITIZATION AND CYBERSECURITY IN ECONOMIC PROCESSES AND E-BANKING IN RECENT YEARS

## ABSTRACT

*The main objective of the article was to identify and characterize the key determinants of the growing importance of the digitization of economic processes, the development of online banking, and the increasing role of cybersecurity in recent years. The study indicates that the most important factors accelerating these processes include the dynamic development of information and communication technologies (ICT), the concept of Industry 4.0, the spread of cloud and mobile solutions, and the development of information systems based on artificial intelligence. The Covid-19 pandemic also played a significant role, accelerating the digitization of business activities and the adaptation of remote communication and customer service models. During the period under review, the use of new online media in business processes increased significantly, which translated into the intensification of e-commerce, e-logistics, e-marketing, electronic payments and settlements, and e-banking. The digitization of these areas has increased the operational efficiency of economic entities, but at the same time has highlighted the importance of advanced cybersecurity systems as a prerequisite for the stable and secure functioning of the digital economy. The article shows that the integration of ICT technologies, Industry 4.0 solutions, and artificial intelligence systems is currently one of the foundations of the digital transformation of enterprises and financial institutions, determining the sustained growth of the importance of digitization and e-banking in the modern economy.*

**KEYWORDS:** *internetization, digitization, information technologies, ICT, Industry 4.0, internet banking, cybersecurity, cybercrime, artificial intelligence, pandemic*

## EXTENDED ABSTRACT

*Objectives: The aim of the article was to identify, systematize, and analyze from multiple perspectives the key determinants of the growing importance of the digitization of economic processes, e-banking, and cybersecurity in recent years. The research also aimed to determine the interrelationships between the development of ICT, the concept of Industry 4.0, artificial intelligence systems, and the transformation of business models of enterprises and financial institutions. An additional goal was to identify exogenous and endogenous factors that have accelerated the process of internetization of economic activity. The article also aimed to assess the impact of the growing scale of digitization on the level of cyber risk and the importance of cybersecurity systems in stabilizing the functioning of the digital economy.*

*Material and methods: The study used a critical analysis of the literature on the subject, including scientific publications, reports from international institutions, and industry studies on digital transformation and cybersecurity. A comparative analysis of secondary data on the dynamics of the development*

*of e-commerce, e-banking, electronic payments, and the implementation of ICT and AI solutions was used. A systemic approach was also used to identify links between technological modernization processes and organizational changes in enterprises and commercial banks. In addition, a cause-and-effect analysis was conducted to determine the impact of selected determinants on the pace and scale of the digitization of economic processes.*

*Results: The results of the analyses indicate that the dynamic development of cloud and mobile technologies and AI-based systems is currently one of the most important factors stimulating the digitization of economic activity and e-banking. A significant increase in the importance of remote communication and customer service channels has been observed, which has translated into the development of e-commerce, e-logistics, e-marketing, and electronic payment systems. The analysis also showed that the accelerated digital transformation has increased the exposure of economic entities to cyber threats, intensifying the need for investment in advanced cybersecurity systems. Furthermore, it was confirmed that the integration of ICT solutions with Industry 4.0 technologies promotes operational efficiency and the creation of new business models in the financial sector.*

*Conclusions: In light of the analyses carried out, it can be concluded that the growing importance of digitalization and cybersecurity is permanent and structural in nature, rather than merely cyclical. The digital transformation of enterprises and commercial banks is becoming a key element in building competitive advantage and organizational resilience in an increasingly uncertain environment. The development of artificial intelligence systems acts as a catalyst for further automation and optimization of economic processes, while generating new regulatory and ethical challenges. Consequently, the effective integration of technological solutions with comprehensive cyber risk management strategies should be a priority for entities operating in the digital economy.*

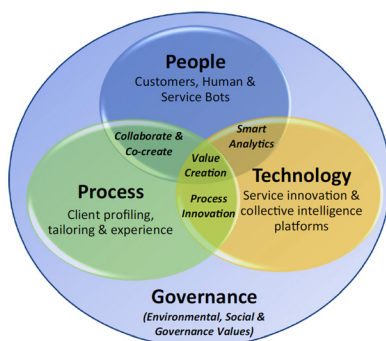
## **INTRODUCTION – THE INCREASE IN RECENT YEARS IN THE SCALE OF DIGITIZATION AND INTERNETIZATION OF BUSINESSES AND PUBLIC INSTITUTIONS**

Based on the research conducted, various determinants of the increase in the scale of digitization and internetization of economic entities and public institutions caused by the Covid-19 pandemic are currently distinguished (Golczak, Golinowski, Kamycki, Lewandowski, Pająk, Płaczek, Prokopowicz, Wesołowski, pp. 67-68, 2021). These determinants include factors such as the increase in the scale of internetization of economic processes in many companies and enterprises that have been forced to temporarily limit the scale

of their business activities due to lockdowns imposed on them by the government. On the other hand, the increase in the scale of internetization of remote communication between public institutions and local government offices (Sarnowski, Prokopowicz, p. 42, 2016) and citizens has enabled these entities to function and provide specific information services thanks to the development of various forms of remote internet communication. Due to the fact that the Covid-19 pandemic has significantly increased the scale of remote Internet communication, online shopping, online settlements and payments, online marketing, promotion or specific offers of products and/or services on social media, and the use of various Internet information services available on smartphones, this has also had an impact on the lifestyle changes (Pizło, A. Mazurkiewicz-Pizło, pp. 106-107, 2017) of many citizens.

Due to the fact that the Covid-19 pandemic has significantly accelerated technological progress in the digitization of various economic and social processes, it is referred to in the literature as the *great accelerator* or *catalyst* of these processes (Amankwah-Amoah, Khan, Wood, Knight, pp. 605-606, 2021). Both positive and negative effects have been identified in the increase in the scale of digitization. Among the negative effects, the most frequently mentioned is the increase in the scale of cybercrime, including in the area of online banking (More, Jadhav, Nalawade, 2016).

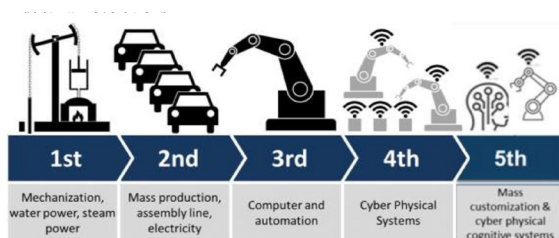
**Figure 1.** *The main components of the ongoing digitization process*



**Source:** N. S. Sewpersadh (2023). *Disruptive business value models in the digital era* (in:) *Journal of Innovation and Entrepreneurship*, Springer, Vol. 12, No. 2. <https://doi.org/10.1186/s13731-022-00252-1>

In view of the above, the Covid-19 pandemic has forced an increase in the scale of internetization and digitization of economic processes (Komorowski, Prokopowicz, 89-90, 2021). Recent years have seen rapid development in internet technologies, ICT, and Industry 4.0 (Nayyar, Naved, Rameshwar, 2023). The Covid-19 pandemic has accelerated the development of these technologies, as the scale of internetization and digitization (Travkina, pp. S485–S486, 2022) of many processes carried out as part of economic activity increased during the pandemic. This growth took place not only in service companies that were subject to lockdowns and sold their services (e.g., catering) via the Internet, but also in many manufacturing companies that were not subject to lockdowns. Many manufacturing companies have improved the efficiency of their production processes by using modern technologies to improve production logistics, quality control systems, and computerized business management support systems. Through the use of new ICT and Industry 4.0 technologies, information security, Internet data transfer, cybersecurity, and other systems have been improved. Many companies have built computerized digital twin systems, which have improved the processes of multi-criteria modeling of economic and other processes, decision-making, and business management. The Covid-19 pandemic, through the use of home quarantines and lockdowns, has forced an increase in the scale of internetization and digitization of remote communication processes and various aspects of economic processes carried out in companies and enterprises (Łobesko, 2020). All five technological revolutions that have taken place so far are presented in the figure below.

**Figure 2.** *Industrial revolutions*



**Source:** A. Clim (2019). *Cyber Security Beyond the Industry 4.0 Era. A Short Review on a Few Technological Promises* (in:) *Informatica economic*, July 2019, vol. 23, No. 2/2019, DOI: 10.12948/issn14531305/23.2.2019.04

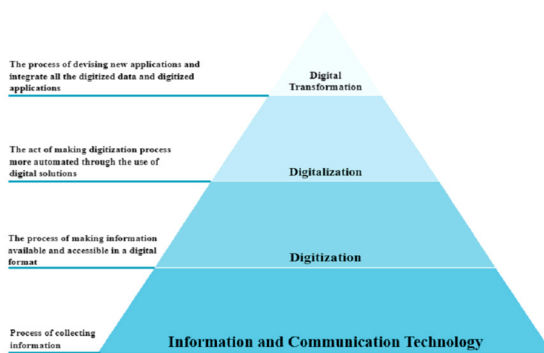
During the Covid-19 pandemic, in order to slow down the spread of the coronavirus and give healthcare institutions more time to prepare for a nationwide epidemic, the government introduced mandatory national quarantines for the general public and lockdowns for selected sectors of the economy, mainly the service sector. Companies and enterprises subject to lockdowns were unable to conduct business under normal conditions and could only provide their services remotely, via the Internet (Chodorek, Chodorek, Pach, 2007) during lockdown periods. This issue affected many companies operating in sectors such as tourism, hospitality, catering, gyms and fitness clubs, physical stores and shopping centers, cultural services provided by museums, galleries, concert halls, theaters, operas, cinemas, etc. In addition, restrictions on the provision of services also affected certain segments of transport services, domestic and international air transport, public transport systems, and many other services (Brouthers, Geisser, Rothlauf, pp. 521-522, 2016).

The possibility of transferring business activities and services to the Internet proved to be a real opportunity for many companies to survive the recession and economic crisis caused by the quarantines and lockdowns introduced in 2020. Since April 2020, sales of various products and services via the Internet have grown rapidly. A significant proportion of citizens who did not make purchases via the Internet before the pandemic were suddenly forced to do so by the pandemic situation and the restrictions imposed by the government. For some product ranges, such as electronics, audio/video equipment, and household appliances, online sales increased several times over during the pandemic. As a result, in some product ranges, the pandemic not only changed customers' purchasing habits, but also significantly increased the profits of stores that switched to online sales and manufacturers of certain types of products for which demand increased significantly during the pandemic.

In view of the above, the Covid-19 pandemic has changed both domestic and international trade in many ways, involving companies and enterprises operating in Poland (Raczkowski, pp. 63-64, 2022). During the pandemic, many companies, especially those in the SME sector, increased the scale of digitization and internetization of economic processes. As part of various anti-crisis measures (Domańska-Szaruga, Prokopowicz, pp. 39-40, 2015), offered SMEs targeted subsidies to increase the level of business digitization

and adapt to the new realities of economic development with greater use of the Internet. The result was an increase in the scale of digitization and internetization of the economy. The scale of development of e-commerce, e-business, e-banking, Internet and mobile banking, e-logistics, e-learning, e-government, remote work, online payments and settlements, etc. increased (Dmowski, Prokopowicz, pp. 342-343, 2010).

**Figure 3.** *Digital Transformation Pyramid*

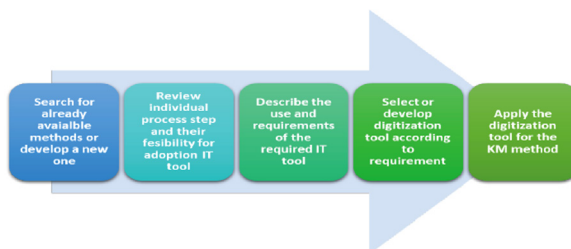


**Source:** S. Panda (2022). *Digitization of Knowledge Management Methods: An Essential Approach* (in:) *International Journal of Knowledge Management and Practices*, No. 10 (2), September 2022, p. 26. DOI: 10.5281/zenodo.7760149; M. SenGupta (2020, March 24). *What is digitization, digitalization, and digital transformation*, ARC advisory, retrieved from <https://www.arcweb.com/blog/what-digitization-digitalization-digital-transformation>.

Due to the fact that during the Covid-19 pandemic, the scale of citizens' purchases of various products and services via the Internet increased, the scale of development of e-commerce (Xu, Li, Wang, Xia 2022), digital marketing, Internet marketing conducted in social media (Mazurkiewicz-Pizło, Pizło, pp. 37-38, 2016), e-logistics, online payments and settlements, the development of e-banking, including online and mobile banking, etc. (Grzywacz, 2016). In view of the above, in recent years, the importance of analyzing the key determinants of the growth in the scale of e-commerce and internet marketing that took place during the Covid-19 pandemic has been increasing. Within this topic, it is also worth examining the issue of the continuation of the aforementioned trends in the growth of the scale of purchases of various products

and services by citizens via the Internet, the increased scale of development of e-commerce, digital marketing, online marketing conducted in social media, e-logistics, online payments and settlements, the development of e-banking, including online and mobile banking, the increase in the scale of digitization and internetization of economic processes in companies and enterprises, investments in business entities aimed at implementing new information technologies (ICT) and Industry 4.0, etc.

**Figure 4.** *Steps of Digitalization Procedure for Knowledge Management Methods*



**Source:** S. Panda (2022). *Digitization of Knowledge Management Methods: An Essential Approach* (in:) *International Journal of Knowledge Management and Practices*, No. 10 (2), September 2022, pp. 30. DOI: 10.5281/zenodo.7760149.

In view of the above, the Covid-19 pandemic has had a serious impact on the development of banking and has become another macro factor that has greatly influenced the development of online and mobile banking. The pandemic has thus become another macro risk factor for banking, forcing systemic and technological changes that have accelerated the development of remote banking. In this context, it was also necessary to increase spending on improving cybercrime risk management systems, improving cybersecurity systems, and better adapting them to smartphone banking (Domańska-Szaruga, pp. 263–264, 2013). For financial markets, including the situation on capital markets in 2020, the Covid-19 pandemic became an unpredictable factor that caused a stock market crash in the first half of March 2020. For this reason, the Covid-19 pandemic, in the context of changes in the economic situation on capital markets in 2020, is often referred to in many publications as a so-called black swan, i.e., a risk factor that had a significant impact but was difficult to predict in advance. Indirectly, the Covid-19 pandemic, i.e. through its impact

on the economic situation on the securities and commodity markets, also had a serious impact on the economic situation in entire national economies. In this way, the pandemic and the lockdowns imposed by the government on selected service sectors of the economy generated a deep recession in the second quarter of 2020. Subsequently, the government's anti-crisis programs of interventionist economic policy based on the so-called Anti-Crisis Shields and Financial Shields generated strong inflation growth from 2021 onwards (Prokopowicz, pp. 117-118, 2022). As part of the anti-crisis measures of interventionist economic policy, both a mild monetary policy (Szybowski, Prokopowicz, Gwoździewicz, pp. 140-141, 2016) based on historically low central bank interest rates and a mild fiscal policy were implemented in 2020. In addition, the National Bank of Poland's belated interest rate hikes (S. Gwoździewicz, Prokopowicz, pp. 217-218, 2018) also contributed significantly to the strong growth in sales of mortgage loans in 2021 offered by commercial banks at historically low interest rates and to the increase in inflation since 2021 (Warner, 2023).

As a result, both the pandemic and the government's interventionist measures have become a source of deep economic crises and increased macroeconomic instability (Raczkowski, Komorowski, pp. 62-63, 2023). In some sectors of the economy, the Covid-19 pandemic caused a sharp decline in the level of economic activity of companies and enterprises in 2020. As a result, in many parts of the world, there was also a short-term decline in greenhouse gas emissions and environmental pollution. This created an opportunity to accelerate the green transition of the economy, including the implementation of new eco-innovations (Pakulska, pp. 61-62, 2020) and green energy technologies as part of the restructuring of business activities carried out in many companies and enterprises (Kwasek, Maciaszczyk, Kocot, Rzepka, Kocot, Gąsiński, Prokopowicz, p. 1942, 2023). Some countries, such as Germany, have taken advantage of this opportunity. Unfortunately, this is not the case in Poland. In addition, the Covid-19 pandemic is interpreted in the context of Internet information security as a significant influencing factor that has led to an increase in the scale of online payments and settlements, the development of Internet and mobile banking, online data transfer, remote Internet communication, etc. This includes the issue of the increase in the scale of cybercrime and the growing importance of improving

cybersecurity techniques, instruments, and systems. As part of the improvement and updating of cybersecurity techniques, instruments, and systems through the use of new ICT technologies and Industry 4.0, it is also necessary to make the necessary changes to legal standards concerning cybersecurity and cybercrime risk management (*Bank Security Forum*, 2016). Appropriate and ongoing updates to the content of legal regulations should be in line with the provisions of the Constitution of the Republic of Poland (Pogódek, Maksymiuk, pp. 28–29, 2016) and the directives, recommendations, and normative documents of the European Union concerning cybercrime and cybersecurity (Gołębiowska, pp. 178–179, 2010).

The sectors and branches of the economy that experienced an increase in economic activity during the Covid-19 pandemic included, above all, online sales, e-commerce, courier companies, and the use of ICT, internet, and Industry 4.0 technologies in business operations. Many companies that had not done so before switched to remote operations conducted electronically via the Internet during the pandemic. As a result, the importance of Internet marketing, including viral marketing and real-time marketing conducted on social media portals, also increased during the pandemic. The development of electronic banking, including Internet and mobile banking, also accelerated. The share of electronic, cashless payments made via the Internet and using electronic bank cards increased (Komorowski, Prokopowicz, pp. 85–116, 2021). More and more citizens stopped using cash when paying in stores and only made contactless payments.

As a result, in mid-2020, some countries increased the limits for all contactless payments made with bank cards. Thus, the Covid-19 pandemic has increased the share of electronic payments in the context of total payments made in national economies, but it does not necessarily lead to the emergence of a completely new cashless economic system. This cashless system has been in place since the 1990s, but in the past it only accounted for a certain proportion of total payments, the financial system, etc., and has gradually grown and undergone successive stages of technological revolution. However, with the spread of the Covid-19 pandemic, this development, i.e., the development of the electronic economy, internet and mobile banking, e-commerce, etc., has accelerated significantly. With the development of electronic online banking, including mobile banking, and the increase in the scale of electronic payments

made by citizens using bank cards and applications installed on smartphones, the space, or rather the online cyberspace, in which cybercriminals can operate, constantly improving and creating new techniques for unauthorized access to electronic banking systems or extorting specific payments made electronically, for example, by setting up fake websites of shops, companies, public institutions (Orłowski, p. 12, 2015), and financial institutions.

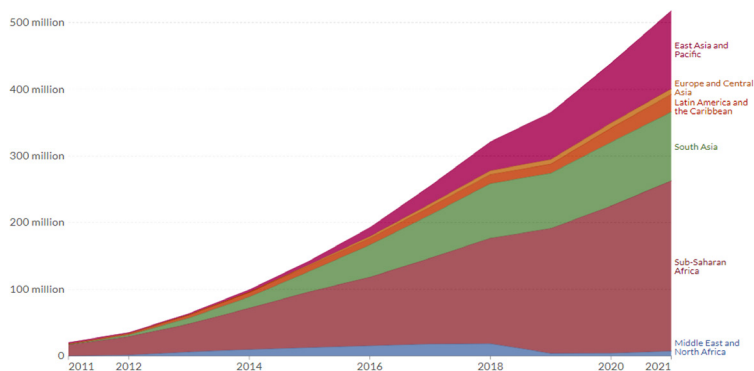
In addition, in recent years, many fake emails created by cybercriminals have been sent to email inboxes (Matosek, Prokopowicz, pp. 223-224, 2017). These emails imitate official emails sent by public institutions and companies, containing content urging the recipient to make a specific payment for a service that will never be provided. Some of these emails contain hidden spyware and malware that reads important personal data from the computer's hard drive (Gałach, Hoc, Jędruszczak, Kowalik and others, 2015), access codes to various portals and online profiles created on various websites by the user of a computer, laptop, tablet, or smartphone. More and more fake emails contain content encouraging the recipient to cooperate, sign a contract with a company that does not exist and in reality has no intention of fulfilling the terms of the contract. In the context of the various economic crises that have become increasingly frequent in recent years and the growth in the scale of various categories of risk, the importance of alliances, cooperation, collaboration, etc. in business is growing. During the Covid-19 pandemic, this issue was exploited by cybercriminals who, for example, impersonated entrepreneurs conducting specific business activities and sent fake emails with proposals for business cooperation (Karaś, pp. 80-89, 2017). These emails contain viruses or malware which, once they have infected a computer, laptop, or smartphone, enable cybercriminals to gain access to sensitive personal data (Gołębiowska, 2017), identification details, logins, and passwords for online banking, etc.

In view of the above, taking into account the issue of the development of the digitalization of the economy and the problem of cyberspace, in which cybercriminals can operate, the following research thesis was formulated: In connection with the Covid-19 pandemic, the increase in the digitalization and internetization of the activities of many companies, as well as the increase in the time spent by citizens on remote work, remote learning through e-learning, an increase in the scale of online shopping, and the use of various

information services available on the Internet, the scale of cybercrime has also increased and the importance of improving cybersecurity techniques and systems has grown.

One element of the development of mobile banking is commercial banks offering their customers remote access to their bank accounts from mobile devices, primarily smartphones. The chart below shows how quickly this type of mobile banking service has developed across different continents.

**Chart 1.** *Active mobile cash accounts*



Number of customer accounts that have made at least one mobile cash payment in the last 90 days of each year. Note: North America is not shown because mobile accounts are not used in this region.

**Source:** *Active accounts* (in:) Portal Our World In Data.org, Technological Change, 6.03.2023, Variable time span 2011-2021 (<https://ourworldindata.org/grapher/active-mobile-money-accounts>; <https://ourworldindata.org/technological-change>); GSMA, 2022, (<https://www.gsma.com/mobilemoneymetrics/#global>).

Due to the dynamic development of online and mobile banking in recent years, the issue of cybercrime and cybersecurity in this area of finance and banking is increasingly being researched and described. In the early stages of the development of electronic banking, the literature primarily described the determinants of this development, the positive aspects of remote banking for bank customers, the IT systems created in banks to enable the development of online electronic banking branches, savings generated in banks resulting from the reduction of operating and personnel costs, and discussions were held on the continuation of this development in the future. At the end of the 1990s,

attempts were made to answer the question: Will there soon be a completely digitized, computerized, automated, and unstaffed banking system? (Shankar, Rishi, pp. 278-279, 2020). In recent years, other issues related to the development of online banking have been considered a priority, worthy of research and description in the literature. In recent years, due to the continuing occurrence of effective Hamerski attacks (Chang, Whitehead, pp. 113–126, 2022) on online banking systems or applications used by bank customers, rapidly developing techniques used by cybercriminals, and constantly emerging new types of computer viruses and malware used by cybercriminals to hack into banking IT systems, gaining access to customers' bank accounts, taking control of customers' bank accounts, the latest literature describes the results of research conducted on the vulnerability of banking IT systems, online and mobile banking systems to cyber threats to information security (Adam, Soliman, Mahtab, 2021).

## **THE ROLE OF ARTIFICIAL INTELLIGENCE-BASED INFORMATION SYSTEMS AND AI AGENTS IN ACCELERATING THE DIGITIZATION OF ECONOMIC PROCESSES AND E-BANKING**

In recent years, the development of artificial intelligence-based IT systems has become one of the key determinants of the growth of economic process digitization and the intensification of e-banking development. The Covid-19 pandemic has significantly accelerated this process, creating conditions conducive to the implementation of advanced algorithmic solutions in the environment of remote work, e-commerce, and digital financial services. Artificial intelligence has ceased to merely support data analysis and has begun to play an active role in decision-making, operational, and communication processes in economic organizations (OECD, 2021).

A particular manifestation of this change is the dynamic growth in the use of so-called AI agents, understood as autonomous or semi-autonomous software systems capable of perceiving their environment, making decisions, and performing specific tasks on behalf of users or organizations. AI agents are finding

increasingly wider application in manufacturing, service, and commercial enterprises, where they support process management, logistics, demand forecasting, and supply chain optimization. Research indicates that the integration of AI agents with ERP and CRM systems can significantly increase operational efficiency and reduce transaction costs (McKinsey Global Institute, 2021).

In the enterprise sector, AI agents are increasingly used in digital marketing and e-commerce, where they are responsible for automating offer personalization, dynamic pricing, and real-time consumer behavior analysis. The use of machine learning algorithms enables companies to respond quickly to changes in customer preferences, which in pandemic and post-pandemic conditions has become one of the key factors in maintaining competitiveness. At the same time, the importance of AI agents in customer relationship management is growing through chatbots and voicebots, which have taken over a significant part of remote communication (Prokopowicz, pp. 95-129, 2023b).

Another important area of application for AI agents is logistics and e-logistics, where autonomous systems support route planning, inventory management, and the prediction of delivery disruptions. The Covid-19 pandemic has revealed the vulnerability of global supply chains, increasing the demand for intelligent solutions capable of adapting to changing market conditions. By analyzing large volumes of data, AI agents enable companies to increase their operational resilience and the flexibility of their business processes (World Economic Forum, 2020).

Particularly advanced and multidimensional applications of AI agents can be observed in the financial sector, especially in commercial banking. In banks, AI-based systems are used in remote customer identification and verification processes, which has become crucial in conditions of limited direct contact. AI agents analyze biometric and behavioral data, enabling the quick and secure launch of electronic banking services.

Another important area of application for AI agents in banking is credit assessment and risk management. Machine learning algorithms allow for the analysis of a much wider range of data than traditional scoring models, leading to more accurate risk assessment and better tailoring of credit offers to customer profiles. This phenomenon is widely analyzed in the literature as a factor increasing the efficiency of the financial sector, but at the same

time raising questions about the transparency and ethics of algorithmic decisions (BIS, 2020).

AI agents are also used in the area of banking security and cybersecurity. Autonomous systems monitor transactions in real time, identifying anomalies and potential financial fraud. With the growth of e-banking and online payments, the importance of these solutions is steadily increasing, as confirmed by analyses by international institutions pointing to AI as a key element of financial protection infrastructure (World Economic Forum, 2020). It is worth noting that the development of AI agents in banking is not limited to operational functions, but increasingly includes strategic and analytical support. These systems are used to forecast market trends, manage liquidity, and optimize the cost structures of financial institutions. As a result, e-banking is transforming into a complex digital ecosystem in which AI is a central element of the decision-making architecture.

At the same time, the development of AI agents as a key determinant of the digitization of economic processes generates new regulatory and organizational challenges. The literature highlights the risks of over-reliance on algorithms, concentration of technology in the hands of large providers, and limited auditability of decisions made by autonomous systems (OECD, 2021). These issues are particularly relevant in the banking sector, where trust and stability of the financial system are of fundamental importance.

From an interdisciplinary perspective, it should be noted that the growing role of AI agents in the economy and e-banking is not only a technological phenomenon, but also an economic, social, and institutional one. This transformation affects the structure of employment, the digital skills of employees, and the relationship between consumers and financial institutions. The Covid-19 pandemic has revealed the potential of these technologies, while accelerating the debate on their responsible and sustainable use (Listopadzka, Prokopowicz, pp. 346-347, 2024).

Accordingly, the development of AI-based information systems, and AI agents in particular, has been one of the most important factors accelerating the digitization of economic processes and the development of e-banking in recent years. This phenomenon is structural and long-term in nature, and its importance will grow with the further integration of AI technology into

Industry 4.0 and the digital economy. Analysis of this issue confirms that the Covid-19 pandemic has not only intensified existing trends, but also permanently changed the direction of development of modern financial and economic systems.

Below, I present a summary of the key areas of economic activity of companies, enterprises, and financial institutions, as well as the areas of activity of commercial banks, in which AI agent applications are used, along with examples of IT solutions, their functionalities, and practical applications in the context of process digitization and the development of e-banking. The summary takes into account interdisciplinary and practical perspectives, supported by current research and industry literature.

**Table 1.** *Applications of AI agents in business activity and commercial banking*

| Area of Activity                                 | Examples of AI Agent-Based Solutions               | Key Functionalities and Applications                                                                                   |
|--------------------------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Marketing and Sales in Enterprises               | AI-driven CRM systems, recommendation engines      | Intelligent customer segmentation, personalized offers, automated and data-driven marketing campaigns, dynamic pricing |
| Customer Service and Support                     | Chatbots and virtual assistants (NLP-based agents) | Automated handling of customer inquiries, 24/7 support, sentiment analysis, reduced response times                     |
| E-commerce and Digital Trade                     | AI recommendation agents for online platforms      | Product recommendations, shopping cart analysis, demand prediction, personalization of the shopping experience         |
| Operational Process Management                   | Agent-based workflow automation systems            | Automation and optimization of business processes, real-time data analysis, process orchestration                      |
| Cybersecurity and Risk Monitoring                | AI anomaly and fraud detection agents              | Real-time monitoring of activities, identification of abnormal patterns, prevention of cyber threats and fraud         |
| Human Resources and Recruitment                  | AI-based recruitment and talent-matching agents    | Automated CV screening, skills matching, decision support in recruitment and onboarding processes                      |
| Finance and Accounting in Enterprises            | Intelligent document processing agents             | Automated invoice processing, accounting automation, financial data classification and reporting                       |
| Commercial Banking – Customer Onboarding         | AI-based eKYC and identity verification agents     | Remote customer identification, biometric verification, secure and fast onboarding processes                           |
| Commercial Banking – Credit Risk Assessment      | AI credit analyst agents                           | Automated credit scoring, advanced risk analysis using alternative data, support for lending decisions                 |
| Commercial Banking – Fraud Detection             | Transaction monitoring AI agents                   | Real-time analysis of payment transactions, fraud prevention, compliance support                                       |
| Commercial Banking – Operational Automation      | Autonomous AI agents for back-office processes     | Automation of accounting, compliance checks, due diligence, and internal banking operations                            |
| Commercial Banking – Financial Advisory Services | AI advisory and wealth management agents           | Personalized investment recommendations, portfolio optimization, decision support for financial advisors               |

**Source:** Own study based on Reuters data.

The use of AI agents in the activities of companies and commercial banks demonstrates the growing importance of this technology as a key factor in the digitization of operational, marketing, analytical, and financial processes. In business practice, AI agents are moving from auxiliary functions, such as chatbots and reporting tools, to tasks with a high degree of autonomy, capable of independently making operational decisions, processing data, and automating multi-stage processes. This confirms the thesis about the fundamental

impact of AI not only on improving business operations, but also on transforming the customer service and digital services model.

In companies and enterprises, AI primarily supports marketing, sales, and e-commerce operations, helping to analyze large sets of customer data, optimize campaigns, and automate contacts. For example, recommendation solutions support the personalization of offer content, and intelligent chatbots handle queries 24/7, which plays a particularly important role in the conditions of intense digital demand observed in the pandemic and post-pandemic period (PKO Bank Polski, 2023).

In the context of banking, AI agents are redefining key service and operational processes. Automated customer verification (eKYC), credit risk analysis, fraud detection, and back-office automation contribute to increasing the efficiency of institutions and reducing operating costs. Current implementations in large commercial banks, such as pilot systems at Citi and collaborations on autonomous operational agents at Goldman Sachs, show a trend toward AI systems that integrate different models and data sources into a single working environment (WSJ, 2026; Reuters, 2026).

However, the challenges and risks that come with the growing autonomy of AI agents cannot be ignored. These issues include algorithmic transparency, responsibility for machine-made decisions, regulatory compliance (e.g., AI ACT in the European Union), and security and privacy risks. Experts emphasize that the lack of clear standards and digital competencies may limit the full exploitation of AI's potential in banking and other sectors, which requires both regulatory oversight and internal AI quality control mechanisms (ZBP, 2025).

From a development perspective, it is worth continuing research on the effectiveness of AI agents in the long term, with particular emphasis on their impact on employment, customer relations, and the business models of companies and banks. Interdisciplinary studies combining technical, economic, and legal knowledge are also necessary to ensure the safe, ethical, and compliant implementation of AI in strategic sectors. In addition, research on the interaction between humans and AI agents seems important, especially in the areas of decision-making and management, which can prevent excessive automation without adequate human control.

In practice, it is recommended to develop Explainable AI (xAI) tools in banking and the economy, which will improve user confidence and legal

compliance, as well as investing in digital education for employees so that they can work effectively with AI systems (Kuiper et al., 2021). Shaping public policies and industry standards that support the transparency, security, and accessibility of AI solutions will become a key element in building a resilient and effective digital economy in the future.

The following table is a summary of the SWOT analysis relating to the key issues discussed throughout this discussion, in particular the use of AI agents and advanced artificial intelligence systems in the economy, the financial sector, and banking. The purpose of the table is to focus on the most important strategic factors in a cross-sectional manner – technological, organizational, regulatory, and socio-economic – while maintaining the interdisciplinary nature of the analysis.

**Table 2.** Concise SWOT analysis of AI agent applications in the economy and the financial sector

| Strengths                                                                         | Weaknesses                                                                           |
|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| High capacity for automation of complex decision-making and operational processes | High implementation and integration complexity with existing (legacy) systems        |
| Scalability and adaptability of AI agents in dynamic market environments          | Shortage of interdisciplinary skills (AI, finance, law, ethics)                      |
| Reduction of operational costs and increased organizational efficiency            | Limited transparency and explainability of algorithmic decisions ("black box" issue) |
| Real-time processing of large-scale and heterogeneous data                        | High initial investment costs and risk of technological lock-in                      |
| Support for service personalization and advanced risk management                  | Strong dependence of outcomes on data quality and availability                       |
| Opportunities                                                                     | Threats                                                                              |
| Development of regulatory frameworks supporting responsible AI adoption           | Regulatory uncertainty and ambiguous legal interpretations                           |
| Integration of AI agents with green transition and sustainable development goals  | Increasing cybersecurity risks and vulnerability to adversarial attacks              |
| Progress in explainable AI (XAI) and algorithmic auditability                     | Loss of social trust due to biased or erroneous automated decisions                  |
| Emergence of new AI-driven business models based on autonomous agents             | Risk of marginalizing human judgment in critical decision-making                     |
| Expansion of human–AI collaboration models (human-in-the-loop)                    | Concentration of advanced AI technologies among dominant market players              |

**Source:** Author's own elaboration.

According to the above, the greatest advantage of AI agents is their ability to autonomously process information and make decisions in complex, multi-dimensional economic and financial systems. The literature emphasizes that, particularly in the banking and financial sector, this translates into better risk management, fraud detection, and product personalization (BIS, 2023; OECD, 2022). At the same time, however, these same characteristics generate significant weaknesses, especially in the areas of algorithmic transparency, decision-making accountability, and the costs of integration with legacy systems.

From the perspective of opportunities, the evolution of the regulatory framework and the development of the concept of trusted and explainable artificial intelligence are of key importance. Research indicates that harmonizing technological innovation (Chrzanowski, Zawada, p. 54, 2018) with the principles of ethics and institutional governance can significantly increase public acceptance and the stability of AI implementations (OECD, 2022). At the same time, the risks associated with technology concentration, cybersecurity, and the potential displacement of human skills remain a real strategic challenge, requiring a systemic and long-term approach.

The conclusions from the abbreviated SWOT analysis suggest that the future development of AI agents should be based on hybrid models combining algorithmic autonomy with expert supervision (human-in-the-loop) and on investments in interdisciplinary competencies. It is also recommended to deepen research on the impact of AI agents on the stability of financial systems, the labor market, and institutional trust mechanisms, as confirmed by current reports from international organizations (BIS, 2023; Russell & Norvig, 2021).

The figure below presents a synthetic overview of the key determinants of the growth of economic process digitization and e-banking in recent years, with particular emphasis on the role of the Covid-19 pandemic and the development of artificial intelligence-based IT systems. The diagram shows the cause-and-effect relationships between exogenous factors (pandemic shock), technological factors (AI and ICT), the process of digital transformation of the economy, and practical applications of AI agents in enterprises and commercial banks. The central category of the model is the digitization of the economy, understood as the process of structural transformation of business, operational, and relational models towards solutions based on data, automation, and network communication. The placement of AI agents at the center of the lower part of the diagram emphasizes their role as implementation tools that operationalize digital transformation in specific areas of economic and financial activity.

**Figure 5.** *Determinants and applications of AI agents in the digitisation of economic processes and online banking*



**Source:** Author's own elaboration.

From an interdisciplinary perspective, the diagram reflects a systemic approach, according to which digital transformation is not solely the result of technology implementation, but rather the result of the interaction of technological, organizational, and institutional factors. As Vial (2019) points out, digital transformation leads to profound changes in the way value is created, cost structures, and stakeholder relationships (Vial, 2019). The diagram fits into this approach, showing that artificial intelligence is not an autonomous factor of development, but a catalyst for changes in the logic of how companies and banks operate. In this context, AI agents in the areas of customer service, predictive analytics, risk management, and banking operations automation are part of a broader process of value chain reconfiguration.

At the same time, the figure points to the ambivalent nature of digitization. On the one hand, the use of AI in e-commerce, e-marketing, credit scoring, and fraud detection systems increases the efficiency, scalability, and personalization of services. On the other hand, the increasing complexity of IT systems generates new systemic risks, particularly in the areas of cybersecurity and data protection. Brynjolfsson and McAfee (2014) emphasize that digital technologies, including advanced automation, bring significant productivity gains, but at the same time lead to structural socio-economic tensions, including labor market polarization and capital concentration (Brynjolfsson and McAfee, 2014). The diagram implies a similar duality: AI as a factor in increasing competitiveness and as a source of new regulatory and ethical challenges.

In the context of the banking sector, the integration of AI agents with risk management and cybersecurity systems is of particular importance. According to BIS (2021) analyses, the use of artificial intelligence in banking improves the accuracy of credit risk assessment and the effectiveness of fraud detection, but at the same time increases the dependence of financial institutions on algorithmic models, whose transparency and explainability remain limited (BIS, 2021). The figure can therefore be interpreted as a model of balance between innovation and financial system stability. The condition for the sustainability of this balance is the development of regulations on data management, cyber resilience, and the responsible use of AI.

The conclusions drawn from the analysis of the diagram indicate that the further growth of digitalization and e-banking will depend on the synergy of three components: technological infrastructure, human capital, and the regulatory environment. Future research should focus on a quantitative assessment of the impact of AI agents on business productivity and financial sector stability, as well as on an analysis of the long-term social effects of decision-making automation. It is also recommended to develop interdisciplinary research combining economics, management sciences, computer science, and law in order to develop models for a sustainable and secure digital transformation.

## **REGULATORY FRAMEWORKS AND FUTURE PERSPECTIVES FOR AI AND CYBERSECURITY IN DIGITAL BANKING**

The rapid development of artificial intelligence and the intensification of digitization processes in the economy and the financial sector have generated a growing need to develop coherent and effective regulatory frameworks. In the European Union, the central instrument of this regulation is the Artificial Intelligence Act (AI Act), adopted in 2024, which introduces a risk-based approach to regulating AI systems. Under this framework, AI applications used in banking, credit scoring, and customer identity verification are classified as high-risk systems, subject to strict requirements regarding transparency, human oversight, and the accuracy and reliability of the data on which they are based. The implementation of the AI Act represents a milestone in shaping the institutional environment for AI in the financial sector, creating both new compliance obligations for institutions and a framework for building social trust in automated systems (European Parliament, 2024).

In parallel with the development of AI regulation, the European Union has taken decisive steps to strengthen the operational and digital resilience of the financial sector through the Digital Operational Resilience Act (DORA), which entered into force in January 2025. DORA establishes uniform requirements for the management of ICT risk in financial institutions, covering areas such as incident reporting, continuity testing, third-party risk management, and information sharing between entities. From the perspective of commercial banks operating in a highly digitized environment, DORA represents a significant systemic change, requiring a comprehensive review of ICT governance structures and investment in advanced risk management systems. The interaction between DORA and the AI Act creates a new regulatory architecture that profoundly reshapes the conditions for the development of e-banking and the deployment of AI agents in financial processes (European Commission, 2022).

An important dimension of future development in the area of cybersecurity in banking is the growing importance of so-called zero-trust security models. Unlike traditional perimeter-based security approaches, the zero-trust architecture assumes that no user, device, or network component should

be considered trusted by default, regardless of their location within the organization's infrastructure. The implementation of this model in commercial banks reflects a fundamental shift in thinking about digital security: from protecting the perimeter to continuously verifying the identity and integrity of all components of the IT environment. In the context of the growing scale of remote banking operations and the increasing use of cloud services, the zero-trust model is becoming a recommended standard for ensuring information security and protecting customer data (NIST, 2020).

Looking at future directions for the development of AI and digitization in the economy, it is worth pointing to the growing significance of quantum computing as a potential transformative technology for both the security and efficiency of digital financial systems. Quantum computers, due to their capacity to perform calculations at speeds many orders of magnitude greater than classical computers, could fundamentally change the landscape of cryptography and, consequently, the principles of cybersecurity in banking. On the one hand, the widespread availability of quantum computing could render current public-key encryption methods obsolete, creating the risk of mass decryption of data currently considered secure. On the other hand, quantum cryptography and post-quantum encryption algorithms represent a new generation of security tools that could dramatically increase the resilience of banking IT systems against cyberattacks. Institutions such as the National Institute of Standards and Technology (NIST) have already initiated the process of standardizing post-quantum cryptographic algorithms, anticipating the need to adapt the security infrastructure of financial institutions to the realities of the quantum era (NIST, 2022).

Another key trend shaping the future of AI in the banking sector is the increasing use of federated learning and privacy-preserving machine learning techniques. These approaches allow AI models to be trained on distributed datasets without the need to centralize sensitive customer data, which addresses one of the fundamental tensions between the requirements of effective machine learning and the principles of personal data protection under the General Data Protection Regulation (GDPR). Federated learning makes it possible for multiple financial institutions to jointly improve fraud detection or credit risk assessment models without sharing confidential client

information. This opens new possibilities for collaborative development of AI in the banking sector while maintaining regulatory compliance and customer trust (Bonawitz et al., 2019).

From the perspective of the long-term development of e-banking, significant attention should also be paid to the growing role of open banking and the ecosystemic transformation of financial services. The implementation of the PSD2 directive in the European Union and the subsequent development of open banking standards have opened the banking market to a wide range of third-party providers (TPPs), including fintech companies and technology giants. This has resulted in the emergence of complex financial ecosystems in which AI agents can operate across the boundaries of traditional institutions, aggregating data from multiple sources, automating financial decisions, and offering customers highly personalized financial services. This development, while bringing substantial benefits in terms of service quality and financial inclusion, simultaneously poses new challenges for regulators in the areas of data sovereignty, systemic risk management, and consumer protection (EBA, 2021).

In conclusion, the analysis of regulatory trends and future technological directions confirms that the development of AI and digitization in the economy and e-banking will be shaped by the interaction of three fundamental forces: technological innovation, regulatory governance, and social trust. The effective management of this interaction will determine whether the digital transformation of financial systems will bring sustainable value to the economy and society as a whole, or whether it will generate new systemic risks and social inequalities. The importance of interdisciplinary research, combining economic analysis with legal, technological, and ethical perspectives, will therefore continue to grow, providing decision-makers with the knowledge necessary to navigate the complex landscape of the digital economy of the future.

## **SUMMARY AND CONCLUSIONS**

The growth of internetization and digitization (Grzegorek, Prokopowicz, Goździewicz, pp. 97-98, 2020) of economic processes and the improvement of the management of public institutions and commercial entities greatly helped to survive the economic crisis caused in 2020 by the Covid-19

pandemic (*COVID-19 to plunge global economy into worst recession since World War*, 2020). During the pandemic, there was an acceleration in the digitization and internetization of both economic processes carried out by commercial enterprises and companies, as well as the organization of remote communication between public service sector offices and institutions and citizens.

The development of ICT and Industry 4.0 (Zhou, Liu, Zhou, 2022) has, on the one hand, led to technological advances in the development of online remote communication, e-commerce, online and mobile banking, e-logistics, e-learning, online video conferencing, online payments and settlements, online marketing on social media portals, etc. (Such-Pyrgiel, Prokopowicz, Gołębiowska, pp. 15-16, 2022). As a result, the environment of online applications and information services is growing, within which cybercrime is developing. On the other hand, the development of ICT and Industry 4.0, including blockchain technology, is generating new solutions that are being used to improve cybersecurity techniques and the process of managing the risk of cybercrime. The above-mentioned processes accelerated during the Covid-19 pandemic.

During the Covid-19 pandemic, many industries and sectors saw an increase in the number of businesses that developed their activities via the Internet, providing their services remotely and selling their products through e-commerce (Sadłowski, Lewandowska-Gwarda, Pisarek-Bartoszewska, pp. 175-176, 2021). Many companies that had not done so before switched to remote operations conducted electronically via the Internet during the pandemic. The importance of Internet marketing, including viral marketing, public relations, video conferencing, etc., conducted via the Internet increased. The development of electronic banking, including Internet and mobile banking, also increased. The share of electronic, cashless payments made via the Internet and using electronic bank cards increased. The percentage of citizens who did not use cash when paying in stores but made contactless payments grew. As a result, the Covid-19 pandemic caused a significant increase in the share of electronic payments in the context of total payments made in national economies (Komorowski, Prokopowicz, pp. 85-116, 2021). The importance of financial transactions carried out remotely, via the Internet, grew. Commercial banks recorded an increase in electronic payments and an increase in the number of transfers made via online banking, including mobile banking.

The above considerations show that the growing importance of the digitization of economic processes and e-banking in recent years is structural and multifactorial in nature, rather than incidental. The intensification of ICT development, the implementation of artificial intelligence-based solutions, and the accelerated adaptation of remote economic interaction models in the context of exogenous shocks, including the Covid-19 pandemic, played a key role. The digital transformation has affected not only the technological layer, but also business models, organizational process architecture, and customer and stakeholder relations. As Vial (2019) emphasizes, digital transformation leads to a fundamental re-configuration of value creation mechanisms, which is reflected in the dynamic development of e-commerce, e-payments, and e-banking (Vial, 2019).

AI agent applications, which operationalize digital transformation in specific areas of business and commercial banking, are of particular importance in this process. Applications in predictive analytics, credit scoring, fraud detection, offer personalization, and customer service automation increase operational efficiency and decision accuracy, but at the same time give rise to new regulatory and ethical challenges. According to BIS (2021) analyses, the use of AI in banking can improve risk management, but requires enhanced supervision, model transparency, and cyber resilience (BIS, 2021). At the same time, Brynjolfsson and McAfee (2014) point out that the development of advanced automation leads to profound structural changes in the economy, including changes in the labor market and the concentration of technological skills (Brynjolfsson and McAfee, 2014).

The most important conclusions from the entire discussion can be summarized in the following points:

1. The digitization of economic processes and e-banking is permanent and forms the foundation of a modern data-driven economy.
2. Artificial intelligence acts as a catalyst for transformation, increasing the efficiency, scalability, and personalization of services.
3. The increased use of AI agents is associated with the growing importance of cybersecurity and technology risk management.
4. The stability of the financial system requires the parallel development of technological innovation and an adequate regulatory framework.

Accordingly, the processes discussed should be viewed from a systemic and interdisciplinary perspective, combining economics, management sciences, computer science, and legal sciences. The digital transformation of businesses and financial institutions is not merely a technological project, but a strategic process of structural change that redefines the relationships between technology, human capital, and regulatory institutions. The further development of e-banking and AI agent applications will depend on the ability to build digital trust, ensure high cybersecurity standards, and shape responsible models for the implementation of artificial intelligence.

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