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# THE COVID-19 PANDEMIC CRISIS AND THE TECHNOLOGICAL REVOLUTION

**Abstract.** The aim of this article is to present the changes referred to as the "fourth industrial revolution" and the role of the crisis caused by the COVID-19 pandemic in accelerating the technological revolution in relation to Polish companies. The ongoing economic downturn has different causes and much broader effects than previous crises. Hence the need to analyze trends (megatrends) in the emergence of innovations initiated or significantly accelerated by the pandemic crisis, and consequently, among other things, the intensification of the digital transformation process.

The study has a theoretical and empirical character. For the research, the authors used the descriptive method with elements of statistical data analysis. The analysis was based on reports of such institutions as the World Intellectual Property Organization, the European Commission and the Central Statistical Office.

*Keywords*: crisis, COVID-19 pandemic, technological revolution, industry 4.0, economy 4.0, digital transformation.

## Introduction

The turn of the 20th and 21st centuries saw the beginning of a process of intense technological change referred to by the term "fourth industrial revolution." The word "revolution" has always meant rapid and radical change. Revolutions have occurred throughout history when new technologies and new ways of perceiving the world caused profound changes in social systems and structures. The vehemence of these changes can last for years. The first profound change in the human way of life occurred about

10,000 years ago and involved a shift from foraging to agriculture and was made possible by the domestication of animals. The agrarian revolution combined the efforts of animals with those of humans for production, transportation and communication. Gradually, the increase in the size of food production, resulted in the growth of human populations, enabling the creation of larger human settlements. This eventually led to urbanization and the creation of cities. The agrarian revolution was followed by a series of three industrial revolutions that began in the second half of the 18th century (Schwab, 2016, p. 11).

The designation of next waves of rapid economic, social and political changes associated with the diffusion of new technology, known as technological revolution, is conventional, and their division was proposed in the 1970s by American sociologist Daniel Bell (Waters, 1996, p. 154). Subsequent revolutions involved a shift from muscle power to mechanical power, evolving to where today, with the fourth industrial revolution, increased cognitive power enhances human production (Schwab, 2016, p. 11).

The first industrial revolution began in Britain in the late 18th century, with the mechanization of the textile industry. The invention of mechanical manufacturing powered by water and steam ushered in the first mechanical automation, which resulted in a huge breakthrough in productivity and consistency of production. The impetus for revolutionary change came with the invention of the steam engine and the construction of railroads, which then ushered in mechanical production (Schwab, 2016, p. 11–13). The second industrial revolution, which began in America in the late 19th century and early 20th century, enabled mass production through the use of electricity and mass production most often associated with the assembly line created by Henry Ford in 1913. The new labor organization provided the opportunity for mass production, which affected the price, quality and availability of products (Bujak, 2017, p. 1341; Schwab, 2016, p. 11–12). Again in America, the third industrial revolution, known as the computer or digital revolution, began in the 1960s. In 1969, the introduction of automation and robotics initiated a new era called Industry 3.0. Electronics and IT, such as the Internet, mobile devices, computers, the cloud and big data, merged into the digital information age (https://von-scheel.com/godfather-of-industry-4-0/). The catalyst triggering this revolution is believed to have been the development of semiconductors, mainframe computers (1960s), personal computers (1970s and 1980s) and the Internet (1990s) (Schwab, 2016, p. 11–12). The release of the Modicon 084 programmable logic controller in 1969, opened the era of industrial automation, giving start to another industrial revolution. The use of PLCs, industrial software and

the gradual implementation of industrial robots changed the organization of production and its management, through direct access to data on the production process. So-called "flexible manufacturing systems" appeared, which resulted in subsequent increase of productivity, quality and expansion of the range of manufactured products. (Bujak, 2017, p. 1341).

We are currently experiencing the fourth industrial revolution, the birth and implementation of the principles of Industry 4.0 or Economy 4.0. The revolutionary technological changes taking place in very many aspects of life coincided with the Sars-Cov-2 pandemic at the beginning of the third decade of the 21st century.

Diseases have affected mankind for centuries, which is why there are known cases of major pandemics in the history. Their effects proved most severe when people began to live in larger concentrations, in cities. One of the major pandemics that oppressed people quite regularly was the plague. But other diseases, such as cholera, typhoid, smallpox, syphilis, leprosy and Spanish flu, were also very devastating. They left a huge imprint on people's mentality, were repeatedly described in literature, were fixed in paintings and sculptures. They affected the conduct of battles, economic turmoil, and the private lives of individuals. Treatment for many centuries was intuitive. Only vaccinations and the recognition of the causes of diseases gave a chance to control them (Krajewska, 2020, s. 17). Progress in medicine has meant that in modern history there have been no cases of disease on the massive scale we have seen before. For this reason, at the turn of 2019/2020, the world has been following with concern the rapid increase in the number of infections with a new coronavirus variant, named COVID-19 by the World Health Organization. The COVID-19 pandemic, like revolutions, has become the cause of rapid technological, economic and social changes. The rapid spread of the new disease and the high mortality rate of patients forced authorities in country after country to "shut down their economies" and seek countermeasures.

The fourth industrial revolution is assumed to have begun in Germany at the beginning of the 21st century with the merging of the digital, physical and virtual worlds, also known as the cyber-physical system, and is based on the digital revolution (Schwab, 2016, p. 11–12). The process was initiated by the German national strategy in 2009, called the "Digital Agenda." One of the creators and driving force behind this strategy was management thinker Henrik von Scheel. In 2011, he first used the term "fourth industrial revolution" and in 2013 an inter-ministerial innovation policy initiative was announced called "Industry 4.0" (https://von-scheel.com/godfather-of-industry-4-0/).

According to H. von Scheel, considered the "godfather" of Industry 4.0, it will emerge in eight evolutionary stages driven by 77 megatrends (https://von-scheel.com/godfather-of-industry-4-0/) and will change every aspect of people's lives, every economy, industry and society on a scale never seen before. It has also never been as complex a process before. The megatrends shown in Table 1 are clashing in the economy and becoming the driving force behind the Industry 4.0 paradigm shift.

**Table 1**

**The collision of 77 Megatrends propel the paradigm shift of the Industry 4.0**

| | |
|---|---|
| Technology Megatrends (19) | Advanced Analytics, Augmented Reality, Augmented Systems, Artificial Intelligence, Advanced Material, Bioinformatics, Blockchain, Cybersecurity, Cloud Computing, Digitalization (IOT), Fusion Energy, Robotics, Smart Automation, Nano-technology, Neuro-technology, Quantum Technology, Web 3.0, 3D Printing, 6G Communications |
| Economic Megatrends (8) | Natural Disasters, Biodiversity loss, Infectious Diseases, Circular Economy, Digital Economy, Demonetize, Economic Power Shift, Redefine of Gross Domestic Product (GDP) |
| Globalization Megatrends (11) | Migration, New Trade Routes, Population Growth, Societal Aging, Inequality, Pollution, Sectoral Shift, Resource Scarcity, Autocratization, Volatility, Populism |
| Regulatory Megatrends (8) | Human Rights, National Security, Environment Protection, Technology and Science, Labor Market, Consumer Protection, Financial Market, Trade and Investment |
| Workforce Megatrends (4) | Mobility, Diversity, Reskilling, Connectedness |
| Consumer Megatrends (10) | Radical Personalization, Reality Merge, Privacy & Security, Convenience, Ethical Living, Sensory Stimulation, Authenticity, Empowered Individual, Value Price Reality, Wellness |
| Demographic Megatrends (8) | Urbanization, Global Power Shift, Shift in Faith, Middle Class, Debt Challenge, Globalization Reset, Cyber Instability, Health and Care |
| Environmental Megatrends (9) | Population, Climate Change, Water Usage, Energy Efficiency, Sixth Mass Extinction, Recycling renewables, Footprint, Waste management, CO2 emission |

Source: prepared on the basis of: https://von-scheel.com/godfather-of-industry-4-0/ [access: 10.10.2023].

As Table 2. shows, this is also related to the successive waves of the fourth industrial revolution." According to H. von Scheel, the first wave of the fourth industrial revolution is from 2009–2016, the second wave is from 2016–2025, and the third wave of change is expected to begin in 2025. Each successive wave brings a series of changes on a global scale.

**Table 2**

**The waves of the "Fourth industrial revolution"**

| 1st wave 2009–2016 | 2nd wave 2016–2025 | 3rd wave 2025... |
|---|---|---|
| Digitalisation | Artifical Intelligence | Quantum Computing |
| Internet of Things | Blockchain | Cyber Security |
| Advanced Analytics | Smart Automation | Neuro and Nano Technology |
| Cloud Computing | 6G Communications | Bioinformatics |
| Robotics | Future of Energy | ..... |

Source: prepared on the basis of: Lightbound R. (2018). *Henrik von Scheel on Industry 4.0 and the AI investment opportunity*, https://insights.roboglobal.com/henrik-von-scheel-industry-4-0 [access: 10.10.2023].

According to K. Schwab, however, the fourth industrial revolution is not just about the intelligent combination of machines and systems. Its scope is much broader. There are simultaneous waves of successive breakthroughs in areas ranging from gene sequencing to nanotechnology, from renewable energy sources to quantum computing. It is the combination of these technologies and their interactions in the physical, digital and biological domains that make the current industrial revolution fundamentally different from previous ones. In this revolution, new technologies and wide-ranging innovations are spreading much faster and more widely than in previous revolutions, which are still developing in some parts of the world. The second industrial revolution has yet to be fully experienced by 17% of the world, as nearly 1.3 billion people still lack access to electricity (Schwab, 2016, p. 12–13).

This also applies to the third industrial revolution, with more than half of the world's population. Most of the more than 4 billion people live in developing countries without access to the Internet. The spindle, a hallmark of the first industrial revolution, took nearly 120 years to spread beyond Europe. By comparison, the Internet spread globally in less than a decade. However, the lesson from the first industrial revolution is still relevant – the degree to which a society adopts technological innovations is a major determinant of progress. The government and public institutions, as well as the private sector, must do their part, but it is also important for society to see the long-term benefits of this process (Schwab, 2016, p. 11–12).

The scope of the fourth industrial revolution is much broader than the previous one. The main differences between the fourth and third revolutions are the widespread (global) access to the Internet. Determinants of the fourth industrial revolution also include (Bujak, 2017, p. 1341):

– a drastic reduction in the cost of data storage (storing 1GB of data in 1995 cost about $10000/year, in today's costs 3 cents a year);
– the increasing number and mobility of Internet-related devices;
– use of renewable energy sources;
– the development of artificial intelligence systems (including machine learning).

Related to the term "industrial revolution," are also the terms "Industry 4.0" and "digital economy," or "ECONOMY 4.0." Industry 4.0 combines embedded systems manufacturing technologies and intelligent manufacturing processes to pave the way for a new technological era that will radically transform industry and manufacturing value chains and business models. It is characterized by a much more ubiquitous and mobile Internet, smaller and more efficient sensors that have become cheaper, and artificial intelligence and machine learning. Digital technologies based on hardware, software and networks are not new, but in a break with the third industrial revolution, they are becoming more sophisticated and integrated, and as a result, are transforming societies and the global economy (Schwab, 2016, pp. 11–12).

The three key success factors of Industry 4.0 according to H. von Scheel are as follows (https://von-scheel.com/godfather-of-industry-4-0/):
– thinking about value, not technology;
– thinking about people, not tools;
– setting clear goals from the beginning.

The Fourth Industrial Revolution marks the birth of INDUSTRY 4.0, but also a series of challenges in transforming the economy into a digital economy, ECONOMY 4.0.

An OECD study titled "Harnessing the Digital Economy for Developing Countries" notes that defining exactly what constitutes a digital economy is problematic, as digital technologies increasingly permeate many aspects of society and the economy. Building on D. Bell's earlier concepts of "information economies" in 1973 (Bell, 1973) and Castells' "network economies" in 1996 (Castells 1996, Castells 2007), the concept of a digital economy is rooted in digital technologies, information networks and the activities that people perform through such networks (Dahlman, Mealy, Wermelinger, 2016, p. 11).

In 2017, UNCTAD's UN Agenda recognized that the new digital economy is based on advanced cyber-physical systems (linking machines, information systems and workers). It encompasses technologies and processes based "in one way or another" on advanced information and communication solutions, such as robotics and manufacturing automation, new data

sources from mobile and ubiquitous internet connectivity, the cloud, big data analytics and artificial intelligence (*The "New" Digital Economy and Development*, 2017, p. 2).

The digital economy is a combination of general purpose technology (GPT) and a range of economic and social activities carried out by people through the Internet and related technologies. It includes the physical infrastructure that digital technologies rely on (broadband lines, routers), the devices (computers, smartphones), the applications they support (Google, Salesforce) and the functionality they provide (IoT, data analytics, cloud computing). The digital economy permeates many aspects of modern life, including retail, transportation, education and agriculture benefiting consumers, businesses and governments (Dahlman, Mealy, Wermelinger, 2016, p. 11). It is identified with the fact of using new technologies – it is simply an economy in which "transactions are done electronically via internet", "resulting from billions of online connections", "being a combination of technology and human activities" (Śledziewska, Włoch, 2020, p. 78). The term ECONOMY 4.0 is also being used more and more often. Its characteristic is the widespread use of digital solutions in traditional sectors of the economy and a change in the model of functioning of the economy (https://przemyslprzyszlosci.gov.pl/gospodarka-4-0-wymyka-sie-dotychczasowym-definicjom-i-miernikom/).

The end of the second decade of the 21st century, brought new challenges related not only to the advances of the fourth industrial revolution, but also to the rising wave of pandemics. In December 2019 and the first quarter of 2020, with the growing number of people infected with the dangerous new SARS-Cov-2 virus, more countries were facing the threat of a pandemic. The first case, a so-called "patient zero," was recorded as early as November 2019 in Wuhan, China (*Chiny: Najwcześniejszy zanotowany przypadek COVID-19 pochodzi z 17 listopada 2019*, 2020). On January 9, 2020, the World Health Organization announced that there is a mysterious pneumonia associated with infection with the as-yet-unknown coronavirus, while 2 months later, on March 11, 2020, it declares COVID-19 pandemic status.

## The covid-19 crisis – the course and effects on the economy

The COVID-19 pandemic, also known as the coronavirus pandemic, is a global disease outbreak. The pandemic has caused global economic disruption, including the worst global recession since the Great Depression.

It is a global crisis because the entire world is experiencing the negative effects associated with the pandemic, but the consequences of the pandemic outbreak have varied across the world's economies in terms of the number of infections relative to the population and how the situation was handled. Countries often used different lockdown policies, which affected the economic situation. Economies dependent on tourism, travel, hospitality and entertainment experienced particularly severe difficulties (Roper, Turner, 2020, p. 509). Emerging and developing markets face additional challenges from unprecedented reversals in capital flows as global risk appetite and currency pressures diminish, as well as coping with weaker health systems and more limited fiscal space to provide support. Moreover, some economies entered the crisis with slow growth or high debt levels (Roper, Turner, 2020, p. 504–505).

The pandemic crisis turned out to be a Black Swan because of its serious consequences, which involved health and life and the inability to stop its spread (Wnorowski, Niklińska, 2020, p. 5). This is undoubtedly an example of an unpredictable and irregular event of enormous magnitude and broad consequences, unexpected to a given observer – usually called a "turkey" – if it not only surprises him, but also harms him (Taleb, 2013, p. 6).

The COVID-19 crisis was different from the previous collapse, with external shocks mainly affecting market dynamics through a decline in demand. The direct supply-side effects of the 2008 crisis were mainly limited to the financial and banking sectors. The disruption at the industrial level was a consequence of the progressive recession rather than the crisis itself. There was an economic shock that affected the economic system, but to a limited degree. The pandemic crisis, on the other hand, differs from the earlier ones in the scope of its consequences (physical and mental health, economic well-being, social change) and also in its geographic reach (global in nature). Therefore, its impact on innovation is different – the importance of technology or technical and scientific knowledge is emphasized, as well as the difficulty of accessing resources on a global scale. Both the virus itself and the lockdowns initiated to slow its spread make it difficult to meet basic human needs (Dahlke et al., 2021, p. 3).

The pandemic crisis has led to widespread changes in the global market, including in innovation activities. H. Chesbrough points out that innovation is often analyzed in terms of cost, and the question of whether to "produce or buy" often depends on which approach costs less. However, during the pandemic, time was so precious that the question of cost became far less important than the ability to find a solution faster (Chesbrough, 2020, p. 410). Crises undoubtedly have an impact on the innovativeness of

entities, but research in this area notes two opposite approaches (Okoń-Horodyńska, 2021, p. 431): innovation suffers during a crisis, or crises are adrenaline for innovation. Innovation can be a driving force in mitigating a crisis, and entrepreneurs implementing it today face challenges to become the innovation leaders of tomorrow. In the past, crises have set a pattern of forcing innovation and changing development trends at the same time. On the one hand, this has led to the emergence of entirely new directions of change, while on the other hand it has accelerated the implementation of trends that have already been observed and projected into the future (Protasiewicz, 2021, p. 487–488).

Private and public entities provided emergency solutions (vaccines), but also implemented digital technologies that helped reduce the impact of the pandemic. Many of the advances that were made in the pandemic involved improvements in productivity, efficiency and even creativity (automation and artificial intelligence, data control, cities). Savings due to them, the resulting production costs have emerged in an economy based on innovation, ideas and information. Information and data have become a new value faster than expected.

## The impact of the COVID-19 crisis on the acceleration of the fourth technological revolution in the Polish economy

Viewed narrowly, the digital economy is reduced solely to the digital sector (IT/ICT) producing basic digital goods and services, while a broader view encompasses economic activities related exclusively or primarily to digital technologies and business models based on digital goods or services, and sometimes all areas of the economy that use ICT, as well as digital activities undertaken by public institutions and individuals (Bukht, Heeks, 2017, p. 3).

Emphasized in the literature, as well as reports from international institutions (including the World Economic Forum and the OECD) as technology trends in the first decades of the 21st century have undoubtedly accelerated as a result of the COVID-19 pandemic in 2020/2021, especially trends already occurring in STI (science, technology and innovation). This has further opened up access to data and publications, increased the use of digital tools, strengthened international cooperation, spurred a number of public-private partnerships and encouraged the active involvement of new players.

Those trends mainly focus on health and information flow. This is also confirmed by the *Most Innovative Companies* ranking published by

the Boston Consulting Group. The ranking shows that six of the 50 most innovative companies in the world in 2023 are from the pharmaceutical industry, with 3 of them ranked higher than in the previous ranking (Table 3.). The highest ranking of 6 was Moderna, moving up one position compared to last year. Pfizer rose from 18th to 11th place during the same period. It was another year of growth for the industry. Already, the report published in 2020, that is, in the early days of the COVID-19 pandemic, brought breakthrough results for the pharmaceutical industry. Nine companies were ranked, three times as many as in the earlier period. The highest ranked was Pfizer. Never before has the industry been so heavily weighted in the list of the most innovative companies. The Pfizer conglomerate ranked 10th, with Merc in 15th place and Novartis in 16th. The US-based Moderna, which only became famous after the discovery of the vaccine, was in 42nd place, and Europe's AstraZeneca was 49th. 2021 Ramón Baeza, managing director of BCG and co-author of the report, noted that innovative companies are better able to cope with the effects of a pandemic, which is considered a catalyst for new projects and solutions (*Most Innovative Companies*, 2023, p. 4; *Najbardziej innowacyjne firmy. Szczepionki pomogły koncernom*, 2021).

**Table 3**

**Ranking of the world's most innovative companies in 2023**

| PLACES 1–10 | PLACES 11–20 | PLACES 21–30 | PLACES 31–40 | PLACES 41–50 |
|---|---|---|---|---|
| 1. Apple | 11. Pfizer (+7) | 21. Roche | 31. Sony (–22) | 41. Saudi Aramco |
| 2. Tesla (+3) | 12. J&J (+15) | 22. Oracle (–3) | 32. Sinopec | 42. Coca-Cola(–6) |
| 3. Amazon | 13. SpaceX | 23. BioNTech | 33. Hitachi (+6) | 43. Mercedes Benz Group |
| 4. Alphabet | 14. Nvidia (+1) | 24. Shell | 34. McDonald's | 44. Alibaba (–22) |
| 5. Microsoft (–3) | 15. ExxonMobil | 25. Schneider | 35. Merck | 45. Walmart (–32) |
| 6. Moderna (+1) | 16. Meta (–5) | 26. P&G (+8) | 36. ByteDance | 46. PetroChina |
| 7. Samsung (–1) | 17. Nike (–5) | 27. Nestle (+22) | 37. Bosch (–11) | 47. NTT |
| 8. Huawei | 18. IBM (–8) | 28. General Electric (+1) | 38. Dell (–24) | 48. Lenovo (–24) |
| 9. BYD Company | 19. 3M (+18) | 29. Xiaomi (+2) | 39. Glencore | 49. BMW |
| 10. Siemens (+10) | 20. Tata Group | 30. Honeywell | 40. Stripe | 50. Unilever |

Source: prepared on the basis of: *Most Innovative Companies 2023. Reaching New Heights in Uncertain Times*, Boston Consulting Group, Boston 2023, p. 4.

The results of the 2023 global innovation survey are in line with other new BCG research, which shows that companies built for the future share a common set of attributes that allow them to perform better, be more resilient to shocks and disruptions, and use innovation to and use innovation to create value faster. In addition to people and technological capabilities (including, importantly, artificial intelligence), one of these attributes is a culture based on innovation (*Most Innovative Companies*, 2023, p. 4; *Najbardziej innowacyjne firmy. Szczepionki pomogły koncernom*, 2021).

State activity, on the other hand, has strengthened trends related to remote work or organizing people's lives through various applications and services (online shopping, instant messaging), also strongly referring to urbanization megatrends (Table 4.). Innovation seems to be enabled by technology-based megatrends that support artificial intelligence, innovative COVID-19 solutions related to health, work and consumption, the use of big data and network technologies (Ebersberger, Kuckertz, 2021, p. 130).

**Table 4**

**The impact on society of technological developments during the COVID-19 crisis**

| Technological development | Innovation logic | Social impact |
|---|---|---|
| Ventilators, vaccines | Time-to-market | Crisis readiness |
| Artificial intelligence, ventilators | Cross-sectoral innovation | Innovation in ecosystems |
| Respirators, sanitizers | Flexible manufacturing systems | Social responsibility |
| Artificial intelligence, robotics | Big data | Intellectual property |
| Wearables, cashless payment, streaming, e-commerce | Technology acceptance | Citizen surveillance |
| Videoconferencing, e-learning, e-gaming | Digitization | Flexible work methods |

Source: (Brem, Viardot, Nylund, 2021, p. 5)

Information and communication technologies (ICT), interchangeably referred to as information and communication technologies, ICT or information technology) refers to a family of technologies that process, collect and transmit information in electronic form (GUS, 2022, p. 46). A narrower term is information technology (IT), which refers to technologies related to computers and software, but not related to communications and networking

technologies. ICTs include tools related to both searching for, collecting, recording and storing information, as well as those for processing, transmitting, reproducing, presenting and liquidating it (Osmańska-Furmanek, Furmanek, 2006, p. 302–304).

The contribution of the ICT sector in GDP in Poland is at a very low level compared to the analyzed EU countries (Table 5.). Only Lithuania has a slightly weaker performance. Romania and Slovenia have the most similar results to Poland. The widening development gap with Hungary, Estonia and Bulgaria is also evident. Across the EU, the ICT sector's share of GDP is below average, with countries with the highest share including: Malta, Sweden and the Czech Republic.

**Table 5**

**ICT sector's share of GDP in Central and Eastern European countries (%)**

| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Average (EU-11) | 3,83 | 4,23 | 4,04 | 3,99 | 3,96 | 3,97 | 4,05 | 4,14 | 4,30 | 4,44 | 4,59 |
| Bulgaria | 4,84 | 4,80 | 4,63 | 4,53 | 4,69 | 4,88 | 5,02 | 5,36 | 5,72 | 6,07 | 6,62 |
| Croatia | 4,14 | 4,06 | 4,56 | 4,00 | 3,85 | 4,05 | 4,02 | 4,14 | 4,16 | 4,31 | 4,38 |
| Czech Republic | 4,44 | 4,39 | 4,34 | 4,35 | 4,34 | 4,27 | 4,24 | 4,27 | 4,36 | 4,56 | 4,71 |
| Estonia | 4,37 | 4,98 | 4,78 | 5,03 | 4,70 | 4,60 | 4,83 | 4,74 | 4,90 | 5,12 | 5,39 |
| Slovakia | 3,68 | 4,61 | 4,43 | 4,70 | 5,00 | 4,18 | 4,35 | 4,01 | 4,30 | 4,13 | 4,31 |
| Slovenia | 3,34 | n.d. | 3,50 | 3,47 | 3,55 | 3,56 | 3,59 | 3,60 | 3,59 | 3,67 | 3,59 |
| Lithuania | 2,16 | n.d. | 2,40 | 2,41 | 2,47 | 2,38 | 2,57 | 2,93 | 2,95 | 3,01 | 3,13 |
| Latvia | 3,27 | 3,36 | 3,51 | 3,40 | 3,46 | 3,74 | 3,74 | 4,15 | 4,53 | 4,69 | 4,92 |
| **Poland** | **3,07** | **3,18** | **3,27** | **3,14** | **3,03** | **3,07** | **3,14** | **3,21** | **3,33** | **3,59** | **3,62** |
| Romania | 3,12 | 3,12 | 3,10 | 3,19 | 3,14 | 3,31 | 3,36 | 3,56 | 3,53 | 3,74 | 3,74 |
| Hungary | 5,70 | 5,61 | 5,90 | 5,69 | 5,78 | 5,58 | 5,71 | 5,62 | 5,96 | 5,95 | 6,13 |

Source: prepared on the basis of Eurostat data https://ec.europa.eu/eurostat/databrowser/view/ISOC_BDE15AG/default/table?lang=en [access: 14.10.2023]

*Digital Challengers* reports, indicate that since the second decade of the 21st century, a key factor in economic development has been the progressive growth of the digital economy among the 10 countries of Central and Eastern Europe (Bulgaria, Croatia, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia). (Novak et al., 2018, p. 10).

According to the *Digital Economy and Society Index (DESI)*, in 2017–2022 Poland ranked 24th among the 27 EU member states. Although the value of the index is below the EU average, the average annual rate of change in Poland is slightly higher, suggesting that Poland is gradually improving its performance in the field of digitization (Table 6.).

**Table 6**

**Changes in the DESI index and its dimensions in Poland compared to the EU**

| | | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|
| **EU** | **DESI (EU)** | **33,7** | **35,9** | **38,6** | **41,7** | **46,2** | **52,3** |
| | Connectivity | 24,8 | 26,6 | 30,6 | 35,1 | 44,3 | 59,9 |
| | Digital public services | 46,7 | 50,7 | 54,2 | 58,3 | 63,2 | 67,3 |
| | Human capital | 41,5 | 41,8 | 42,8 | 44,0 | 44,6 | 45,7 |
| | Integration of digital technology | 21,8 | 24,5 | 26,9 | 29,3 | 32,7 | 36,1 |
| **Poland** | **DESI (PL)** | **24,9** | **27,1** | **29,8** | **33,2** | **36,5** | **40,5** |
| | Connectivity | 20,5 | 22,9 | 26,4 | 32,5 | 38,2 | 46,5 |
| | Digital public services | 34,3 | 38,2 | 42,2 | 46,7 | 51,1 | 55,8 |
| | Human capital | 32,2 | 32,8 | 33,9 | 34,7 | 36,3 | 37,0 |
| | Integration of digital technology | 12,7 | 14,6 | 16,7 | 19,0 | 20,6 | 22,9 |

The overall DESI index, calculated as a weighted average of the four main DESI dimensions.
Source: own compilation based on: DESI, 2022, https://digital-agenda-data.eu/ [access: 15.10.2023]

The level of connectivity, as a component of DESI, is increasing in Poland at a slower pace than the EU average (the largest gap in mobile broadband, similar values to the EU average in fixed broadband coverage and demand). Digital public services in this ranking are still below the EU average (Poland ranked 22nd). By 2030, as part of the Digital Decade, 100% of the provision of key public services to EU citizens and businesses is to be done online. Poland should increase efforts in improving digitization and encourage the use of e-government services. The average annual growth in the value of human capital is the slowest among the DESI dimensions analyzed (Table 6.). Although the rate of change of human capital in Poland is slightly higher than in the EU, there is still a gap in the level of sophistication and development of skills of Internet users.

According to the *Global Innovation Index*, the level of ICT infrastructure in 2013 was rated at 43.4, resulting in Poland ranking 51st globally. In 2022, on the other hand, the score improved significantly, rising to 86.4 (22nd place), and the level of ICT infrastructure was rated as an innovation strength, particularly due to the high score of government Internet services and e-participation in electronic forms of information sharing and decision-making (*Global Innovation Index*, 2022, p. 187).

DESI digital technology integration consists of: digital intensity, digital intensity of business use and e-commerce. Poland's performance is well below the EU average. Between 2017 and 2022, the digital intensity index and the intensity of digital technology use in enterprises were about 1.5 times lower, while the e-commerce subcomponent was about 2.5 times lower than the EU average. However, according to Eurostat data, Poles (right after Estonians) are the nation with the least concerns about payment security among EU countries (1.6% in Polish citizens reported such concerns in 2019, while the EU average is 6.5%) (DESI, 2022).

In 2019. Computerworld, together with its partner ABB, conducted a survey among Polish enterprises, in which the authors wanted to find out how Polish companies view the idea of Economy 4.0. Entrepreneurs representing large enterprises and small and medium-sized businesses were asked whether they are preparing or implementing an already developed strategic plan for digital transformation, and who are – and who should be – the leaders of digital transformation in entities of the manufacturing sector. An ambiguous picture emerged from the survey. On the one hand, Polish companies are only at the beginning of their journey toward Economy 4.0. Innovation and the degree of sophistication of manufacturing processes are low, and mature and widely adapted solutions dominate among the systems and technologies used. A plan that indicates the vision, goals and responsibility for the activities conducted has only 14% of the companies surveyed, and 11% intend to prepare such a document in 2019. The main obstacle to implementing innovative projects turns out to be high investment expenses. On the other hand, almost half (48%) of respondents say they are implementing smaller projects in the area of Economy 4.0 without a comprehensive transformation strategy. Among the systems planned for implementation, solutions such as IIoT, RPA systems and predictive maintenance are mentioned first. Companies are seeing the benefits of implementing Economy 4.0 projects: 70% of companies expect an increase in efficiency or productivity of manufacturing processes, 59% a reduction in costs, and 40% an increase in revenue (*W drodze ku Gospodarce 4.0*, 2019, p. 4).

The main motives of entrepreneurs taking steps to transform to Economy 4.0 are the desire to grow and seek new sources of revenue (48%) and the need to meet market competition (45%). Optimization and digitization of imperfect processes will allow companies to maintain their ability to compete in global markets. "Locomotive" of the changes are large enterprises and corporations, which force cooperators to maintain certain standards of cooperation in terms of quality assurance, expected performance or communication methods. As a result, smaller companies will adapt their business models to meet the demands of these larger ones, including by adapting innovative digital technologies. This is confirmed by the survey results: 1/3 of respondents indicated the desire to meet customer expectations as a motivating factor to move towards Economy 4.0. Next, the expectations of owners or shareholders were mentioned (24%), as well as the care for the company's image and the way it is perceived externally, including social expectations (23%). The dynamically developing Polish economy, the employee market and the evolution of companies towards Western models mean that Polish, often family-owned companies, see an opportunity to match the standards and efficiency of their closest competitors with foreign capital in the implementation of Economy 4.0 innovations and technologies. (*W drodze ku Gospodarce 4.0*, 2019, p. 16).

Among the many expected benefits of undergoing digital transformation are an increase in the efficiency or productivity of manufacturing processes (70% of enterprises), cost reduction (59% of respondents) and obtaining higher revenues (40% of respondents). By optimizing processes, companies want to earn more. Changing business models, digitization and automation of processes, also in the sphere of robotization, translate directly into the productivity of enterprises. 12% of respondents see these projects as an opportunity to reduce employment. Simple jobs will be done by robots, but modern manufacturing systems will require workers with new skills. 25% of respondents see an improvement in the quality of products and services among the benefits of implementing digitization projects, while another 19% see an improvement in processes related to customer service (*W drodze ku Gospodarce 4.0*, 2019, p. 17).

In 2020, industrial digitalization faced its biggest test to date. Faced with the biggest health and economic crisis in recent history, companies across the industry have been forced to take extraordinary measures to protect their employees and keep their operations running. While some struggled to maintain operations in the face of shortages of workers or raw materials, others struggled to keep up with the sudden surge in demand. Have the technologies of the ongoing Fourth Industrial Rev-

olution (or Industry 4.0) helped these companies in their efforts? (Agrawal et al., 2021)

The Ernst & Young report shows that the crisis caused by the pandemic has accelerated digital transformation in Polish enterprises. Individual levels of management have recognized the need to introduce it and the opportunities it brings, contributing to increased efficiency – 21% of respondents showed a willingness to use new technologies despite running traditional industries (Ernst&Young, 2021, p. 3–5).

Enterprises believe that digital transformation will accelerate their growth, and more than half cite the desire to adapt to customer expectations as the reason for initiating it. It is important to highlight the strong impact of the pandemic on taking steps towards digital transformation – 27% of respondents cited the COVID-19 pandemic as a decisive factor in implementing digital transformation in their company. It is undoubtedly worth mentioning the barriers indicated in the survey: too high costs (35% of respondents). employees' fears of change (28%), lack of skills or resources (25%) or the specifics of the business (23%) (Ernst&Young, 2021, p. 11, 27).

The pandemic period has shown that the transformation to the digital world brings benefits, optimizes work and processes. It allows you to maintain or increase access to customers and improve the process of customer service, e.g. an online visit to a doctor, and additionally increases availability (access to the service for 24 hours). In the "Smart Industry Polska 2020" survey, 70% of respondents indicated that their companies started digitization only because of the pandemic – however, it mainly concerned the way they work. It was also emphasized that contact and cooperation with contractors played an important role in the digitization process (Ministerstwo Rozwoju, 2020, p. 40–41).

## Summary

Many organizations treat digital transformation as a risk. Nevertheless, an even greater risk is the lack of action and falling behind the competition and the growing expectations of increasingly demanding customers. The current economic and social situation provides entities with many challenges, which on the one hand may be an opportunity to increase efficiency (e.g. by increasing sales or accompanying services), but on the other hand an obstacle to running a business. The period of the coronavirus (COVID-19) pandemic in 2020/2021 shows that despite the extremely difficult economic situation, it is also an opportunity to accelerate some positive phenomena

in the area of innovation, as well as more broadly in accelerating the fourth technological revolution. Crucial in this respect seems to be primarily the approach of entities (especially managers) to the need to implement information and communication technologies and innovative solutions in this area. The pandemic crisis has made it possible to accelerate these transformations, which in the era of the COVID-19 pandemic had to be applied out of necessity. Subsequent changes entail an increase in the awareness of entities, which should also be supported by the state policy in this area.

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