

The Impact of Government Spending on DESI Indicators in Poland

Jakub Boratyn, Barbara Kesler

Abstract: **Background:** Digital transformation reshapes Poland's economy and society, yet Poland still falls short of digital maturity, particularly in digital skills and in the uneven adoption of technology across sectors. **Research objectives:** The study assessed the level and dynamics of digital transformation in Poland using DESI indicators and analysed the institutional conditions that support the implementation of disruptive technologies through patterns of public expenditure. **Research design and methods:** The analysis drew on Eurostat DESI variables (2018–2024) and COFOG public expenditure categories, and applied correlation and regression analyses to examine the relationships between categories of government spending and digital transformation indicators. **Results:** Strong positive correlations emerge between electronic information sharing and safety (0.88) and environmental protection (0.87). Public services expenditure demonstrates the strongest impact ($\beta = 23.53$), while education shows paradoxical negative coefficients ($\beta = -20.02$), suggesting substitution effects or structural deficiencies. **Conclusions:** Poland's digital transformation follows complex patterns. Strategic investment in digital government infrastructure creates leverage points, yet safeguards must prevent the erosion of the education and cultural sectors. Therefore, inclusive development requires integrated fiscal approaches that balance technological progress with traditional services.

Keywords: digital transformation, DESI indicators, public expenditure, COFOG classification, Poland

JEL Codes: H50, O33, O38

Suggested citation:

Boratyn, J. & Kesler, B. (2026). The Impact of Government Spending on DESI Indicators in Poland. *Social Entrepreneurship Review*, 1, 136–152. <https://doi.org/10.15678/SER.2026.1.08>

Introduction

Digital transformation exerts inevitable and irreversible effects, making citizens increasingly aware of how profoundly these intertwined processes restructure socio-economic life. Consequently, an extensive and rapidly growing literature now addresses it, spanning themes from its technological and organisational dimensions within businesses (Verhoef et al., 2021; Ji & Li, 2022), through its ethical and societal implications (Karaś, 2025; Roša, 2021), to its measurement through composite policy indices such as the Digital Economy and Society Index (DESI) (Bruno et al., 2023). However, scholars have devoted comparatively less attention to the structure of public expenditure and the extent to which it translates into measurable digital transformation outcomes at the country level. Existing studies treat public spending as a general precondition for digitalisation and other significant paradigms, such as the green transition (Stutzmann & Koos, 2026), without disaggregating expenditure into functional categories

that could be linked systematically to specific outcomes. Furthermore, earlier assessments compare countries rather than the functional composition of expenditure (Mandl et al., 2008; Afonso et al., 2010). As a result, the literature cannot yet establish which categories of public expenditure, according to the Classification of the Functions of Government (COFOG) are most strongly associated with the technological progress captured by indicators such as DESI, and through which institutional mechanisms this relationship operates. The COFOG includes public services, safety, economic affairs, environmental protection, housing, health, recreation, education, and social protection (Eurostat, 2011).

The identified gap warrants closer examination, particularly in Poland. Poland merits this focus because its digital economy combines strong performance in connectivity with persistent structural deficits in digital skills, the availability of information and communication technology (ICT) specialists, and lagging business digitalisation relative to the European average (European Commission, 2025). In response to the identified gap, this article assesses how the structure of public expenditure classified according to COFOG relates to the level of digital transformation in Poland, as measured through DESI indicators, and considers the institutional conditions that support the implementation of selected technologies. Therefore, the study formulated three hypotheses:

H1: Expenditure on public services is positively associated with digital transformation outcomes in Poland, as administrative digitalisation generates spillover effects throughout the economy (Layne & Lee, 2001; Cordella & Paletti, 2019).

H2: Expenditure on education is positively associated with DESI indicators, consistent with human capital theory (Hanushek & Woessmann, 2011; Selwyn, 2016).

H3: Expenditure on environmental protection is positively associated with DESI indicators, reflecting the digital–green twin transition hypothesis (Muench et al., 2022).

Beyond its direct economic and administrative effects, digital transformation also reshapes the conditions under which social entrepreneurship operates, as digital skills, connectivity, and public-sector support increasingly determine whether social enterprises can scale their impact and reach underserved communities. Research on digital social innovation and social entrepreneurship documents this relationship, showing that digital capabilities, platform infrastructures, and supportive public-sector frameworks strengthen social enterprises by making their entrepreneurial process more fluid and their agency more distributed across digitally connected actors (Nambisan, 2017). This perspective underlines why the functional structure of public expenditure matters for building the digital and institutional foundations of inclusive development. Given the exploratory nature of this study and the constraints of available time-series data, the research aimed to identify potential associations rather than to establish definitive causal relationships. Mapping Polish public expenditure priorities against digital progress provides a starting point for future, more granular analyses within the social entrepreneurship ecosystem.

Literature Review

First and foremost, digital transformation entails the integration of the physical and virtual realms, whose boundaries gradually blur to form a unified cyber-physical world (Cellary, 2019s). In the digital economy era, disruptive innovations act as paramount catalysts for change (Korpus, 2021) by building ecosystems of relatively more advanced products and services, stimulating competitiveness, cutting costs, and raising productivity (Małkowska et al., 2021; Kraus et al.,

2021). Furthermore, digital technologies gradually transform economic relations and the labour market at the macroeconomic level, creating new positions and needs, while redistributing financial risk (Tiutiunyk et al., 2021). The diffusion of digital innovations also carries adverse consequences for both the economy and individual enterprises, such as escalating threats of cyberterrorism and cybercrime, labour displacement, structural unemployment, and the misalignment of strategic objectives due to an excessive focus on short-termism (Tiutiunyk et al., 2021; Karaś, 2025). Therefore, scholars widely accept that digital transformation admits a dual perspective.

This duality stands out most clearly in the European Union, where policymakers pursue the digital and green transitions as interconnected, and occasionally conflicting, policy objectives (Barbero et al., 2025; European Commission, 2021a). On the one hand, pro-ecological ambitions and technological advances clearly reinforce each other, as smart solutions enable the oversight, simulation, virtualisation, and data analysis needed to improve efficiency and mitigate the negative environmental impact of economic activities (Muench et al., 2022). On the other hand, claims about integrating environmental objectives with digital development appear partially mutually exclusive, given the staggering energy demands of digital infrastructures and because rapid technological progress exacerbates the risk of the digital divide and social inequalities (Czyżewska-Miszat & Cabańska, 2023).

The Essence of Digital Transformation

Digital transformation constitutes a multidimensional process integrating technological, organisational, and business changes rather than merely introducing new digital tools. It redesigns business models, processes, and value creation through the strategic use of ICTs while responding to changing customer expectations and competitive pressures (Adamczewski, 2020; Berman, 2012; Ji & Li, 2022; Verhoef et al., 2021). Technologies such as cloud computing, artificial intelligence, big data analytics, the internet of things, blockchain, and automation solutions enable this transformation and together create the technological foundations of the Fourth Industrial Revolution (Mooney & Williams, 2024; Śledziwska & Włoch, 2020).

Beyond technology, digital transformation represents a strategic process requiring organisational adaptation, leadership, and the development of digital capabilities. Its success depends not only on technological investment but also on whether organisations can redesign structures, processes, and competencies while aligning digital initiatives with long-term strategic objectives (Gobble, 2018; Piccoli et al., 2024; Verhoef et al., 2021). Consequently, digital maturity reflects the combined effect of technological readiness, organisational capabilities, and human leadership, whereas insufficient adaptation sustains persistent digital divides, particularly among small and medium-sized enterprises (SMEs) (Linthorst & de Waal, 2020; Thordsen & Bick, 2023; Kania, 2025).

Digital transformation also carries broader societal and ethical implications. Beyond improving efficiency and innovation, it reshapes social interactions, consumption patterns, and labour markets while raising concerns about privacy, surveillance, algorithmic bias, and unequal access to digital technologies (Bounfour, 2016; Roša, 2021; Karaś, 2025). Accordingly, digital transformation qualifies as a socio-technical process whose long-term success depends on balancing technological progress with responsible governance, ethical principles, and inclusive development.

Measuring Digital Transformation

Digital transformation aligns with Sustainable Development Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation (Global Goals, n.d.), so assessments regularly monitor how nations implement this paradigm. According to Małkowska et al. (2021), accurately measuring the methods and intensity of digital transformation across European countries remains challenging, further complicated by the need to integrate the societal, economic, and firm-level dimensions.

Researchers have therefore developed numerous indices that, drawing on diverse methodologies, monitor technological progress across various spheres. Figure 1 presents the conceptual framework for this study and groups key policy indices into four thematic pillars: (1) Infrastructure and Accessibility; (2) Human Capital, Digital Literacy and Talent; (3) Cyber-Resilience and Institutional Trust; and (4) Socio-Economic Impact and Innovation.

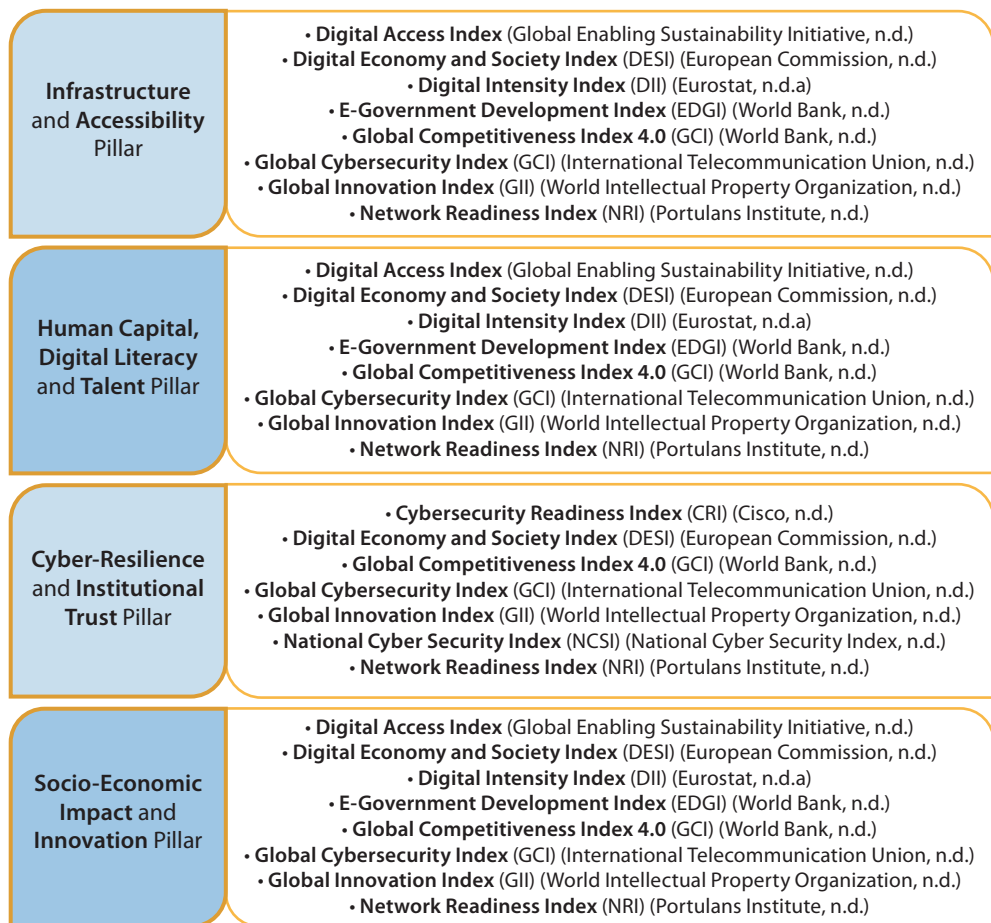


Figure 1. Sample Indicators and Metrics of Digital Transformation

Source: own elaboration.

These pillars situate the DESI within a broader landscape of transformation metrics. Whereas the Infrastructure pillar groups indices centred on connectivity (e.g., Network Readiness Index, Digital Access Index), the Human Capital pillar draws on dimensions from the Global Innovation Index and Global Competitiveness Index 4.0. Similarly, the Cyber-Resilience and Socio-Economic pillars integrate specialised indices such as the National Cyber Security Index and Digital Intensity Index. Within this framework, the DESI serves as a core metric for observing the scale of the digital divide across connectivity, human capital, use of internet services, and notably the integration of emerging technologies and the digital transformation of public and government services (Bruno et al., 2023).

The classification presented here covers only a portion of the indicators used by national and international institutions to monitor the effects of digitalisation. Nevertheless, this segmentation underscores that multiple, partially overlapping policy domains and several cross-cutting concerns shape digital transformation (Giest et al., 2025). Crucially, these domains correspond directly to the functional structure of public expenditure. This alignment between measurement pillars and expenditure categories provides the analytical foundation developed below.

Thematic analysis at the individual level enables a more precise diagnosis of skills and technological gaps, which any strategic action plan should address first (Lis et al., 2024). European Union legislation states that the indicators, aligned with the digital targets for 2030, serve a monitoring and enforcement function for national economies (European Commission, 2025). Although this aggregate digitisation measurement tool – structured around 30 sub-indicators – has garnered both support and criticism, Goliński (2019) contends that it lacks sufficient focus on the causal factors, constitutive elements, and driving forces behind the transformations. Contrary to appearances, contemporary indicators focus exclusively on technologies with tangible effects, so the methodology treats some experimental technologies superficially or omits them altogether.

European nations commit to annual reporting on four cardinal areas: digital skills, digital infrastructure, the digitalisation of business, and the digitalisation of public services (European Commission, n.d.a). The first area identifies the share of a country's population using the internet and their self-assessed digital skills, which matter fundamentally in the modern era, yet these competencies vary sharply with age (European Commission, n.d.a; Stofkova et al., 2022). In turn, digital infrastructure concerns connectivity, since the European Union aims to interconnect the continent through telecommunications, mobile networks, fixed structures, internet cables, and satellites (European Commission, n.d.b). Indicators of business digitalisation prioritise how enterprises across diverse industries implement specific mature technologies to enable convergence, availability, and competitiveness (European Commission, n.d.a). Finally, indicators of online access to public services assess the degree of digitalisation and the penetration rate within public administration and services (European Commission, n.d.a; Świącicki, 2022).

Poland leads in only a few areas of digital transformation, namely access to high-bandwidth networks and high-performance connectivity (European Commission, 2025). Digital maturity nevertheless remains a long-term objective, as numerous challenges confront both policymakers and citizens. The primary dilemmas involve insufficient digital skills, which expose parts of society to digital exclusion and to the persistent digital divide, particularly among vulnerable groups such as the elderly, people with disabilities, ethnic minorities, individuals with lower incomes, and those in remote areas (Tomczyk et al., 2023). Moreover, a distinct gap emerges by enterprise location, size, and sector: in Poland the digital divide separates metropolitan centres

from less urbanised peripheries, and transnational corporations from the SME sector (Eurofound, 2023; Kania, 2025). Therefore, Polish decision-makers build institutional frameworks so that their policies answer these technological asymmetries, and allocate expenditure to support digital transformation.

Public Expenditure, Institutional Capacity, and Digital Transformation

Any innovation strategy operates under the principle of triple co-evolution, which spans the production level, the informal institutional level, and the formal regulatory frameworks that foster and stimulate development at both the national and the international level (Borrás, 2004; Britchenko, 2024). This triadic alignment emerges most clearly in digital transformation, where formal policy-making bodies act as the primary architects of change. Consequently, scholars increasingly urge governments to adopt a holistic approach to national digital agendas, treating digital transformation as a highly interactive ecosystem that requires a shared vision, agile strategies, sustained political commitment, and formalised institutional collaboration (Hanna, 2018). These multifaceted objectives demand significant financial outlays, drawn primarily from the European Union budget and other specialised EU funds, including targeted programmes (e.g., Digital Europe Programme, Connecting Europe Facility, Horizon Europe, and Creative Europe), national budgets, and the private sector, which remains largely autonomous from direct state control (Britchenko, 2024; European Commission, 2026). The success of this digital ecosystem depends not merely on mobilising financial resources effectively, but on aligning institutional capacity strategically.

A growing literature examines how public expenditure patterns, investment prioritisation, and institutional frameworks jointly shape digital transformation outcomes. It rests on the assumption that the allocation of government spending and the institutional capacity to deploy it effectively determine the accessibility, quality, and reach of digital public services (Lynn et al., 2022). Within this context, scholars no longer view public expenditure merely as a static fiscal necessity, but as a dynamic, strategic lever that enables public administrations to become context-sensitive, digital-ready, and interoperable across sectors and borders (Millard, 2023). Comparative research on public spending preferences confirms this approach, showing that citizens, policymakers, and other decision-makers increasingly treat digital and green transformation (the twin transition) as intertwined budgetary priorities competing for the same fiscal space within national budgets (Stutzmann & Koos, 2026). Nonetheless, traditional spending categories still dominated the structure of Polish public expenditure in 2024 – most notably social protection (18.3% of gross domestic product, GDP), economic affairs (6.1% of GDP), and health (6.1% of GDP) (Eurostat, n.d.b). Moreover, recent evidence suggests that the effectiveness of digital government investment depends less on the absolute volume of allocated funds than on the institutional capacity to absorb, coordinate, and operationalise them in ways that convert digital infrastructure into measurable governance performance (Efthaltidou et al., 2025).

Public expenditure, understood in the context of digital transformation as the principal channel through which government investment priorities and institutional capacity translate into concrete digital infrastructure, services, and skills (Lynn et al., 2022), constitutes the fundamental mechanism without which the public sector could not implement innovative solutions at all, or only under severe constraints. Generally, the literature regards public expenditure for digitalisation as an instrument of state intervention that corrects market failures. Public

institutions may spend it directly, channel it to private enterprises through tax incentives or direct grants, or direct it towards collaborative projects involving cross-sectoral stakeholders (Mikołajczyk, 2018; Cox & Gagliardi, 2009).

Thus, at the level of individual government functions, research on e-government and public-sector digitalisation indicates that expenditure on public administration generates spillover effects across the wider economy, as digitised public services lower transaction costs for firms and households and create demand for complementary private digital services (Layne & Lee, 2001; Cordella & Paletti, 2019). However, the effectiveness of such investment ultimately hinges on whether institutions can safeguard data quality and address hidden data gaps, ensuring that digital expenditure delivers inclusive and efficiency-enhancing outcomes rather than reproducing structural inequalities (Giest & Samuels, 2020). In turn, human capital theory links expenditure on education to the accumulation of digital skills, repeatedly identified as one of the most persistent bottlenecks of digital transformation, both in Poland and across the European Union (Hanushek & Woessmann, 2011; Selwyn, 2016). Furthermore, a less explored channel concerns environmental expenditure: insofar as the digital and green transitions form interconnected policy objectives (Muench et al., 2022), spending on environmental protection may be associated with digital transformation outcomes through investment in smart infrastructure and monitoring systems.

Despite the theoretical plausibility of these mechanisms, three key terms require clearer conceptual delimitation: institutional conditions, institutional capacity, and public expenditure efficiency. Institutional conditions denote the formal and informal rules, administrative structures, and governance arrangements within which public authorities design and implement digitalisation policy (North, 1990). Institutional capacity refers more specifically to whether these authorities can convert budgetary resources into effective policy outcomes – in the present research, measurable progress in DESI indicators – through appropriately targeted expenditure categories, rather than to the level of expenditure itself (Millard, 2023). Finally, public expenditure efficiency denotes the extent to which a given level of spending within a functional category translates into intended outcomes, which depends on the quality of institutional absorption capacity rather than on input volume alone (Mandl et al., 2008; Afonso & Kazemi, 2017). This distinction matters, since higher spending does not automatically imply higher institutional effectiveness, which also depends on the allocation, administrative capacity, and diffusion pathway through which expenditure reaches its intended functional domain (Rogers, 2003).

In sum, although the literature extensively documents the drivers of digital transformation, it often overlooks the interplay between functional expenditure and institutional capacity. This study addresses that gap by proposing that digital transformation in Poland reflects not merely fiscal volume, but the outcome of a complex institutional process. In this framework, government spending functions as the foundational resource, while institutional capacity mediates, converting budgetary inputs into tangible digital outcomes through targeted functional categories.

Research Method and Material

In this study, we utilized data from Eurostat concerning DESI variables focused on digital transformation and Polish public expenditure represented by individual COFOG classifications. The period 2018–2024 was selected due to the absence of historical data that could be

integrated with the current analysis. Furthermore, DESI indicators containing missing values in particular years were excluded from the dataset. Given the limited temporal scope of available data, the study maintains an observational character, as the high p-values indicate a lack of statistical significance in the results.

Characteristics of Research Variables

Public Expenditure Variables

The study operationalised the public expenditure variables through the COFOG framework, the internationally recognised OECD standard for classifying government expenditure, which enables comparability across European countries (Eurostat, 2011; Afonso et al., 2010). The analysis covered nine functional expenditure categories: public services, public safety, economic affairs, environmental protection, housing, health, recreation, education, and social protection. Together, these categories capture the principal areas through which governments allocate resources and may influence digital transformation.

Several expenditure categories link directly to developing and implementing digital technologies. Public services and safety expenditure supports the digitalisation of administration, cybersecurity, and justice systems (Gil-Garcia et al., 2018; Chan & Bennett Moses, 2016), while expenditure on economic affairs and environmental protection supports digital innovation, smart infrastructure, environmental monitoring, and resource optimisation (Brynjolfsson & McAfee, 2014; Hilty & Hercheui, 2010). Similarly, digital platforms, smart city solutions, electronic health records, telemedicine, and other e-health applications increasingly reshape housing and health (Batty et al., 2012; Aanestad et al., 2017).

The remaining expenditure categories capture the broader societal dimension of digital transformation. Education develops digital competencies and human capital (Hanushek & Woessmann, 2011; Selwyn, 2016), whereas recreation and social protection illustrate how digital technologies influence cultural participation, public media, and the accessibility and efficiency of welfare services (Belfiore & Bennett, 2008; Peeters & Schuilenburg, 2018). Collectively, these expenditure functions frame how public resource allocation relates to different dimensions of digital transformation.

Digital Transformation Variables (DESI Indicators)

The study derived the digital transformation variables from the DESI, which assesses digital development across European Union member states (European Commission, 2021b). The selected indicators capture key dimensions of digital transformation, including the adoption of big data analytics, electronic invoicing, electronic information sharing, online sales, cross-border e-commerce, social media use, and the number of unicorns. Collectively, these variables capture the diffusion of digital technologies among enterprises and public institutions, the digitalisation of administrative processes, and the integration of digital tools into economic activity (Mayer-Schönberger & Cukier, 2013; Gil-Garcia & Sayogo, 2016; Sila, 2013).

The selected indicators cover complementary dimensions of digital transformation. Big data analytics, electronic information sharing, and e-invoicing capture the digital maturity of public administration and organisational processes (Höchtel et al., 2016; Klievink et al., 2017), whereas online sales, cross-border e-commerce, social media, and unicorns reflect business digitalisation, innovation capacity, market internationalisation, and the growth of the digital economy (Kaplan & Haenlein, 2010; Gomez-Herrera et al., 2014; Lee et al., 2015; Kenney & Zys-

man, 2019). Together, these indicators span technological adoption, digital public services, entrepreneurial innovation, and the digital competitiveness of the economy.

Justification for Variable Selection

To address the methodological limitations identified during the review process, the empirical analysis was based on Spearman's rank-order correlation coefficient (ρ) rather than multivariate regression. This non-parametric approach suits small samples and assesses monotonic associations without assuming linearity or normality of the data (Field, 2018; Schober et al., 2018). Given the limited number of annual observations (2018–2024), the findings remain exploratory associations rather than evidence of causal relationships, in line with the observational nature of the study.

Results and Discussion

Table 1. Spearman's Correlation Results

COFOG	DESI indicator	Spearman's ρ	p -value	Significance
Public Services	Big data	0.201	0.7028	
Public Services	e-invoicing	−0.146	0.7825	
Public Services	electronic information sharing	0.495	0.3182	
Public Services	cross-border online sales	0.495	0.3182	
Public Services	online sales	0.27	0.6042	
Public Services	social media	0.495	0.3182	
Public Services	unicorns	0.4	0.4315	
Public Services	DESI	0.507	0.3046	
Safety	Big data	0.617	0.1923	
Safety	e-invoicing	−0.733	0.0972	
Safety	electronic information sharing	0.904	0.0135	*
Safety	cross-border online sales	0.904	0.0135	*
Safety	online sales	0.802	0.0547	
Safety	social media	0.904	0.0135	*
Safety	unicorns	0.826	0.0426	*
Safety	DESI	0.802	0.0547	
Economic Affairs	Big data	0.37	0.4699	
Economic Affairs	e-invoicing	−0.679	0.1381	
Economic Affairs	electronic information sharing	0.717	0.1087	
Economic Affairs	cross-border online sales	0.717	0.1087	
Economic Affairs	online sales	0.543	0.2657	
Economic Affairs	social media	0.717	0.1087	
Economic Affairs	unicorns	0.618	0.1911	
Economic Affairs	DESI	0.6	0.208	
Environmental Protection	Big data	0.783	0.0653	

COFOG	DESI indicator	Spearman's ρ	p -value	Significance
Environmental Protection	e-invoicing	-0.6	0.208	
Environmental Protection	electronic information sharing	0.904	0.0135	*
Environmental Protection	cross-border online sales	0.904	0.0135	*
Environmental Protection	online sales	0.802	0.0547	
Environmental Protection	social media	0.904	0.0135	*
Environmental Protection	unicorns	0.89	0.0175	*
Environmental Protection	DESI	0.926	0.008	**
Housing	Big data	-0.073	0.8907	
Housing	e-invoicing	0.493	0.3205	
Housing	electronic information sharing	0.141	0.7893	
Housing	cross-border online sales	0.141	0.7893	
Housing	online sales	-0.068	0.8987	
Housing	social media	0.141	0.7893	
Housing	unicorns	0.139	0.7925	
Housing	DESI	0.169	0.7489	
Health	Big data	0.783	0.0657	
Health	e-invoicing	-0.626	0.1835	
Health	electronic information sharing	0.667	0.1479	
Health	cross-border online sales	0.667	0.1479	
Health	online sales	0.638	0.1731	
Health	social media	0.667	0.1479	
Health	unicorns	0.702	0.1203	
Health	DESI	0.783	0.0657	
Recreation	Big data	-0.623	0.1864	
Recreation	e-invoicing	0.754	0.0832	
Recreation	electronic information sharing	-0.635	0.1755	
Recreation	cross-border online sales	-0.635	0.1755	
Recreation	online sales	-0.698	0.1228	
Recreation	social media	-0.635	0.1755	
Recreation	unicorns	-0.688	0.131	
Recreation	DESI	-0.516	0.2946	
Education	Big data	-0.302	0.5609	
Education	e-invoicing	0.127	0.8103	
Education	electronic information sharing	-0.185	0.7262	
Education	cross-border online sales	-0.185	0.7262	
Education	online sales	-0.324	0.5314	
Education	social media	-0.185	0.7262	
Education	unicorns	-0.288	0.5801	

COFOG	DESI indicator	Spearman's ρ	p -value	Significance
Education	DESI	-0.118	0.8243	
Social Protection	Big data	0.463	0.3552	
Social Protection	e-invoicing	-0.802	0.0547	
Social Protection	electronic information sharing	0.478	0.3375	
Social Protection	cross-border online sales	0.478	0.3375	
Social Protection	online sales	0.429	0.3965	
Social Protection	social media	0.478	0.3375	
Social Protection	unicorns	0.441	0.3809	
Social Protection	DESI	0.486	0.3287	

Source: own elaboration.

The correlation analysis showed that few relationships between COFOG expenditure categories and DESI indicators reached conventional levels of statistical significance. Environmental protection expenditure showed the strongest and most consistent positive associations, correlating significantly with the overall DESI index ($\rho = .926, p = .008$), electronic information sharing ($\rho = .904, p = .013$), cross-border online sales ($\rho = .904, p = .013$), social media use ($\rho = .904, p = .013$), and the unicorn indicator ($\rho = .890, p = .018$). By commonly accepted interpretation guidelines, these coefficients indicate very strong positive monotonic associations (Schober et al., 2018). Although these findings do not demonstrate causal effects, they suggest that higher environmental protection expenditure coincided with better performance across several dimensions of digital transformation during the analysed period.

One explanation lies in the growing convergence between environmental and digital policy objectives within the European Union. Environmental protection investment frequently accompanies expenditure on smart infrastructure, environmental monitoring systems, digital public services, and data-driven management solutions, reflecting the twin transition (Muench et al., 2022). Consequently, the observed associations may indicate that governments implement environmental expenditure priorities alongside broader digitalisation initiatives rather than as an isolated policy domain.

Public safety expenditure also showed statistically significant positive associations, particularly with electronic information sharing ($\rho = .904, p = .013$), cross-border online sales ($\rho = .904, p = .013$), social media ($\rho = .904, p = .013$), and unicorns ($\rho = .826, p = .043$). These findings align with previous studies emphasising that digital public administration and cybersecurity infrastructure increasingly support the broader digital ecosystem by improving institutional interoperability and strengthening public trust in digital services (Cordella & Paletti, 2019; Janowski, 2015). Nevertheless, because the analysis rests on very few observations, these relationships remain preliminary empirical patterns that require validation on longer time series or panel data.

In contrast, the remaining expenditure categories exhibited weak or statistically insignificant correlations with DESI indicators. Public services expenditure, in particular, displayed positive coefficients for several indicators but never reached statistical significance. Similarly, expenditure on education failed to demonstrate the expected positive association with digital transformation outcomes. Although this result appears inconsistent with human capital theory (Hanushek & Woessmann, 2011; Selwyn, 2016), it does not show that educational expenditure

hinders digital transformation. Several alternative explanations remain plausible. Educational investment typically generates effects over far longer periods than the present dataset covers, while aggregate COFOG expenditure does not distinguish between general educational spending and expenditure specifically devoted to digital competencies. Furthermore, digital transformation depends on numerous complementary institutional, technological, and socio-economic factors that the present analysis omits. Consequently, the absence of statistically significant relationships remains inconclusive rather than contradictory.

Overall, the findings suggest that the relationship between public expenditure structure and digital transformation in Poland varies across functional expenditure categories. The results provide empirical support for the proposition that some expenditure areas – notably environmental protection and public safety – are more closely associated with digital development than others. However, the observed correlations do not establish the direction of influence and provide no evidence of expenditure effectiveness or institutional capacity. Expenditure levels alone cannot fully capture institutional quality or the mechanisms that translate public resources into digital outcomes. The present findings therefore identify potential areas for further investigation rather than definitive policy effects.

Conclusions

This study examined the relationship between the functional structure of public expenditure, classified according to the COFOG framework, and selected indicators of digital transformation measured by the DESI in Poland for 2018–2024. The authors deliberately limited the analysis to an exploratory assessment of monotonic associations using Spearman's rank-order correlation coefficient. Consequently, the findings evidence statistical association rather than causal relationships.

As the Results and Discussion section shows, expenditure on environmental protection and public safety produced the strongest and statistically significant associations, whereas the remaining categories showed limited or statistically insignificant relationships with DESI indicators.

The empirical evidence supports the proposed hypotheses only in part. The data did not confirm H1 or H2: neither public services expenditure nor education expenditure showed statistically significant associations with digital transformation outcomes. By contrast, H3 received empirical support: environmental protection expenditure showed strong and statistically significant positive associations with the overall DESI index and several individual indicators, providing preliminary evidence consistent with the twin transition perspective (Muench et al., 2022).

The research also carries clear limitations. The analysis rests on a short annual time series, which substantially restricts statistical inference and prevents the identification of causal mechanisms. Furthermore, COFOG expenditure categories constitute broad functional aggregates and cannot distinguish investments directly related to digitalisation from other public expenditure within the same policy domain. Consequently, the reported associations remain preliminary empirical patterns that require verification on longer time series, panel datasets covering multiple European countries, or more detailed expenditure classifications combined with institutional quality indicators. Such approaches would apply more advanced econometric techniques and allow future studies to investigate the causal pathways linking public expenditure, institutional capacity, and digital transformation.

In sum, the study links the structure of public expenditure to selected dimensions of digital transformation, although the strength of these relationships differs considerably across expenditure categories. The findings indicate that environmental protection and public safety expenditure displays the strongest associations with digital development, whereas the data yielded no comparable evidence for public services or education in the analysed period. Therefore, these conclusions offer an exploratory contribution to the literature, providing a foundation for future research rather than definitive evidence on the effectiveness of public expenditure in supporting digital transformation.

References

- Aanestad, M., Grisot, M., Hanseth, O., & Vassilakopoulou, P. (Eds.). (2017). *Information infrastructures within European health care*. Springer.
- Adamczewski, P. (2020). Ku inteligentnej gospodarce w czasach transformacji cyfrowej. In M. Sosnowski & A. Żabiński (Eds.), *Teoretyczne i aplikacyjne wyzwania współczesnych procesów gospodarczych* (pp. 13–23). Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
- Afonso, A., & Kazemi, M. (2017). Assessing public spending efficiency in 20 OECD countries. In *Inequality and finance in macrodynamics* (pp. 7–42). Springer.
- Afonso, A., Schuknecht, L., & Tanzi, V. (2010). Public sector efficiency: Evidence for new EU member states and emerging markets. *Applied Economics*, 42(17), 2147–2164.
- Barbero, J., Collado, A., & Rodriguez-Crespo, E. (2025). The twin transition in the European Union: Assessing regional patterns of EU-funded investments. *European Planning Studies*, 33(10), 1801–1821. <https://doi.org/10.1080/09654313.2025.2528882>
- Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., ... & Portugali, Y. (2012). Smart cities of the future. *The European Physical Journal Special Topics*, 214(1), 481–518.
- Belfiore, E., & Bennett, O. (2008). *The social impact of the arts: An intellectual history*. Palgrave Macmillan.
- Berman, S. J. (2012). Digital transformation: Opportunities to create new business models. *Strategy & Leadership*, 40(2), 16–24. <https://doi.org/10.1108/10878571211209314>
- Borrás, S. (2004). System of Innovation Theory and the European Union. *Science and Public Policy*, 31(6), 425–433. <https://doi.org/10.3152/147154304781779787>
- Bounfour, A. (2016). *Digital futures, digital transformation: From lean production to acceluction*. Springer International Publishing.
- Britchenko, I. (2024). Transformacja cyfrowa i tworzenie innowacyjnej gospodarki Unii Europejskiej. *Rocznik Administracji Publicznej*, 2024, 311–332. <https://doi.org/10.4467/24497800RAP.24.019.20237>
- Bruno, G., Diglio, A., Piccolo, C., & Picicelli, E. (2023). A reduced composite indicator for digital divide measurement at the regional level: An application to the Digital Economy and Society Index (DESI). *Technological Forecasting and Social Change*, 190, 1–16. <https://doi.org/10.1016/j.techfore.2023.122461>
- Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. W. W. Norton & Company.
- Cellary, W. (2019). Przemysł 4.0 i Gospodarka 4.0. *Biuletyn Polskiego Towarzystwa Ekonomicznego*, 3(86), 48–52.
- Chan, J., & Bennett Moses, L. (2016). Is big data challenging criminology? *Theoretical Criminology*, 20(1), 21–39.
- Cisco. (n.d.). 2025 Cisco Cybersecurity Readiness Index. <https://newsroom.cisco.com/c/r/newsroom/en/us/a/y2025/m05/cybersecurity-readiness-index-2025.html>
- Cordella, A., & Paletti, A. (2019). Government as a platform, orchestration, and public value creation: The Italian case. *Government Information Quarterly*, 36(4), 101409. <https://doi.org/10.1016/j.giq.2019.101409>
- Cox, D., & Gagliardi, D. (2009). The public/private nexus of R&D. *IPTS Working Papers on Corporate R&D and Innovation*, 6.
- Czyżewska-Miszat, D., & Cabańska, J. (2023). Podwójna transformacja w UE – stan obecny i wyzwania dla cyfrowej i zielonej Europy. *Scientific Journal of Polish Economic Society in Zielona Góra*, 108–123. <https://doi.org/10.26366/PTE.ZG.2023.249>
- Efthalitsidou, K., Spinthiropoulos, K., Vittas, G., & Sariannidis, N. (2025). Digital Governance, Democracy and Public Funding Efficiency in the EU-27: Comparative Insights with Emphasis on Greece. *Information*, 16(9), 795. <https://doi.org/10.3390/info16090795>

- Eurofound. (2023). *Ethical digitalisation at work: From theory to practice*. Publications Office of the European Union. <https://assets.eurofound.europa.eu/f/279033/4f27f0b5ac/ef22018en.pdf>
- European Commission. (2021a). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: 2030 Digital Compass: The European way for the Digital Decade* (COM(2021) 118 final). <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021DC0118>
- European Commission. (2021b). *Digital Economy and Society Index (DESI) 2021*. Publications Office of the European Union.
- European Commission. (2025). *Commission Staff Working Document: DESI 2025 methodological note* (SWD(2025) 295 final). <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52025SC0295>
- European Commission. (2026). *Funding for Digital in the 2021–2027 Multiannual Financial Framework*. <https://digital-strategy.ec.europa.eu/en/activities/funding-digital>
- European Commission. (n.d.a). *DESI dashboard for the Digital Decade (2023 onwards)*. <https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/indicators>
- European Commission. (n.d.b). *Policies: Connectivity*. <https://digital-strategy.ec.europa.eu/en/policies/connectivity>
- Eurostat. (2011). *Manual on sources and methods for the compilation of COFOG statistics*. Publications Office of the European Union.
- Eurostat. (n.d.a). Glossary: Digital Intensity Index (DII). *Statistics Explained*. [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Digital_Intensity_Index_\(DII\)](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Digital_Intensity_Index_(DII))
- Eurostat. (n.d.b). Government expenditure by function for Poland 2024. <https://ec.europa.eu/eurostat/cache/visualisations/economy/government-expenditure/>
- Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). Sage.
- Fozer, D., Szirmai, P., Nagy, T., Tarjani, A. J., Toth, A. J., Haaz, E., ... & Benko, T. (2022). Life cycle, PESTLE and multi-criteria decision analysis of CCS process alternatives. *Journal of Cleaner Production*, 290, 125747.
- Giest, S., McBride, K., Nikiforova, A., & Sikder, S. K. (2025). Digital & data-driven transformations in governance: a landscape review. *Data & Policy*, 7, e21. <https://doi.org/10.1017/dap.2024.47>
- Giest, S., & Samuels, A. (2020). For good measure: data gaps in a big data world. *Policy Sci*, 53, 559–569. <https://doi.org/10.1007/s11077-020-09384-1>
- Gil-Garcia, J. R., Dawes, S. S., & Pardo, T. A. (2018). Digital government and public management research: Finding the crossroads. *Public Management Review*, 20(5), 633–646.
- Gil-Garcia, J. R., & Sayogo, D. S. (2016). Government inter-organizational information sharing initiatives: Understanding the main determinants of success. *Government Information Quarterly*, 33(3), 572–582.
- Global Enabling Sustainability Initiative. (n.d.). *#DigitalAccessIndex*. <https://digitalaccessindex-sdg.gesi.org/#sect-hp-deepdives>
- Global Goals. (n.d.). *9 Industry, innovation and infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*. <https://globalgoals.org/goals/9-industry-innovation-and-infrastructure/>
- Gobble, M. M. (2018). Digital strategy and digital transformation. *Research-Technology Management*, 61(5), 66–71. <https://doi.org/10.1080/08956308.2018.1495969>
- Goliński, M. (2019). Pomiar gospodarki cyfrowej w badaniach Unii Europejskiej. *Roczniki Kolegium Analiz Ekonomicznych Szkoły Główniej Handlowej w Warszawie*, 54, 155–169.
- Gomez-Herrera, E., Martens, B., & Turlea, G. (2014). The drivers and impediments for cross-border e-commerce in the EU. *Information Economics and Policy*, 28, 83–96.
- Hanna, N. (2018). A role for the state in the digital age. *J Innov Entrep*, 7(5). <https://doi.org/10.1186/s13731-018-0086-3>
- Hanushek, E. A., & Woessmann, L. (2011). The economics of international differences in educational achievement. In E. A. Hanushek, S. Machin, & L. Woessmann (Eds.), *Handbook of the Economics of Education* (Vol. 3, pp. 89–200). Elsevier.
- Hilty, L. M., & Hercheui, M. D. (2010). ICT and sustainable development. In *What kind of information society? Governance, virtuality, surveillance, sustainability, resilience* (pp. 227–235). Springer.
- Höchtl, J., Parycek, P., & Schöllhammer, R. (2016). Big data in the policy cycle: Policy decision making in the digital era. *Journal of Organizational Computing and Electronic Commerce*, 26(1–2), 147–169.
- International Telecommunication Union. (n.d.). *Global Cybersecurity Index*. <https://www.itu.int/en/ITU-D/Cybersecurity/pages/global-cybersecurity-index.aspx>
- Janowski, T. (2015). Digital government evolution: From transformation to contextualization. *Government Information Quarterly*, 32(3), 221–236.

- Ji, X., & Li, W. (2022). Digital transformation: A review and research framework. *Frontiers in Business, Economics and Management*, 5(3), 21–27. <https://doi.org/10.54097/fbem.v5i3.1898>
- Kania, M. (2025). Cyfrowa transformacja sektora MŚP – bariery, korzyści i przyszłe scenariusze rozwoju. *Rozprawy Społeczne*, 19(1), 261–276. <https://doi.org/10.29316/rs/211185>
- Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of social media. *Business Horizons*, 53(1), 59–68.
- Karaś, J. (2025). *Transformacja cyfrowa w teorii i w praktyce*. Wydawnictwo Uniwersytetu Łódzkiego.
- Kenney, M., & Zysman, J. (2019). Unicorns, Cheshire cats, and the new dilemmas of entrepreneurial finance. *Venture Capital*, 21(1), 35–50.
- Klievink, B., Romijn, B. J., Cunningham, S., & de Bruijn, H. (2017). Big data in the public sector: Uncertainties and readiness. *Information Systems Frontiers*, 19(2), 267–283.
- Korpus, J. (2021). Przejęcia technologiczne w erze gospodarki cyfrowej. In M. Johann (Ed.), *Gospodarka cyfrowa i postcyfrowa a przedsiębiorstwo* (pp. 75–88). Oficyna Wydawnicza Szkoły Głównej Handlowej w Warszawie.
- Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., & Roig-Tierno, N. (2021). Digital transformation: An overview of the current state of the art of research. *Sage Open*, 11(3). <https://doi.org/10.1177/21582440211047576>
- Layne, K., & Lee, J. (2001). Developing fully functional e-government: A four stage model. *Government Information Quarterly*, 18(2), 122–136. [https://doi.org/10.1016/S0740-624X\(01\)00066-1](https://doi.org/10.1016/S0740-624X(01)00066-1)
- Lee, N., Sameen, H., & Cowling, M. (2015). Access to finance for innovative SMEs since the financial crisis. *Research Policy*, 44(2), 370–380.
- Linthorst, J., & de Waal, A. (2020). Megatrends and disruptors and their postulated impact on organizations. *Sustainability*, 12(20), 1–25. <https://doi.org/10.3390/su12208740>
- Lis, M., Poszytek, P., Jefmański, B., Fila, J., Jeżowski, M., & Kotelska, J. (2024). *Transformacja cyfrowa przedsiębiorstw w dobie Przemysłu 4.0*. Akademia WSB.
- Lynn, T., Rosati, P., Conway, E., Curran, D., Fox, G., & O’Gorman, C. (2022). Digital Public Services. In: Digital Towns. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-91247-5_3
- Małkowska, A., Urbaniec, M., & Kosała, M. (2021). The impact of digital transformation on European countries: Insights from a comparative analysis. *Quarterly Journal of Economics and Economic Policy*, 16(2), 325–355. <https://doi.org/10.24136/eq.2021.012>
- Mandl, U., Dierx, A., & Ilzkovitz, F. (2008). *The effectiveness and efficiency of public spending*. European Commission, Directorate-General for Economic and Financial Affairs.
- Mayer-Schönberger, V., & Cukier, K. (2013). *Big data: A revolution that will transform how we live, work, and think*. Houghton Mifflin Harcourt.
- Mikołajczyk, K. (2018). Public R&D expenditure and their impact on private R&D: complementarity or substitution? Analysis for Central and East European countries. *Acta Universitatis Lodzensis. Folia Oeconomica*, 3(335), 171–188. <https://doi.org/10.18778/0208-6018.335.12>
- Millard, J. (2023). *Impact of digital transformation on public governance – New forms of policy-making and the provision of innovative, people-centric and inclusive public services*, Manzoni, M. and Schade, S. (Eds.), Publications Office of the European Union, Luxembourg, <https://doi.org/10.2760/204686>
- Mooney, J. G., & Williams, M. L. (2024). Enabling technologies of the Fourth Industrial Revolution. In Z. Simsek, C. Heavey, & B. C. Fox (Eds.), *Handbook of research on strategic leadership in the Fourth Industrial Revolution* (pp. 35–61). Edward Elgar Publishing.
- Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M., & Scapolo, F. (2022). *Towards a green and digital future*. Publications Office of the European Union. <https://doi.org/10.2760/977331>
- Nambisan, S. (2017). Digital Entrepreneurship: Toward a Digital Technology Perspective of Entrepreneurship. *Entrepreneurship Theory and Practice*, 41(6). <https://doi.org/10.1111/etap.12254>
- National Cyber Security Index. (n.d.). *Descriptions of indicators*. <https://ncsi.ega.ee/indicators/>
- North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press.
- Peeters, R., & Schuilenburg, M. (2018). Machine justice: Governing security through the bureaucracy of algorithms. *Information Polity*, 23(3), 267–280.
- Piccoli, G., Grover, V., & Rodriguez, J. (2024). Digital transformation requires digital resource primacy: Clarification and future research directions. *The Journal of Strategic Information Systems*, 33(2). <https://doi.org/10.1016/j.jsis.2024.101835>
- Portulans Institute. (n.d.). *Network Readiness Index*. <https://networkreadinessindex.org/>
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
- Rośa, A. (2021). Exploring the role of ethical issues in the context of digital transformation. *Trends Economics and Management*, 38(2), 23–33. <https://doi.org/10.13164/trends.2021.38.23>

- Selwyn, N. (2016). *Is technology good for education?* Polity Press.
- Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia & Analgesia*, 126(5), 1763–1768.
- Sila, I. (2013). Factors affecting the adoption of B2B e-commerce technologies. *Electronic Commerce Research*, 13(2), 199–236.
- Stofkova, J., Poliakova, A., Stofkova, K. R., Malega, P., Krejnus, M., Binasova, V., & Daneshjo, N. (2022). Digital skills as a significant factor of human resources development. *Sustainability*, 14(20). <https://doi.org/10.3390/su142013117>
- Stutzmann, S., & Koos, S. (2026). Funding the future: understanding public spending preferences on the green transition and digitalization in advanced democracies. *Journal of Public Policy*, 1–23. <https://doi.org/10.1017/S0143814X26101172>
- Śledziwska, K., & Wloch, R. (2020). *Gospodarka cyfrowa: Jak nowe technologie zmieniają świat*. Wydawnictwo Uniwersytetu Warszawskiego.
- Święcicki, I. (2022). *How to measure the Digital Decade: Recommendations for an evolution of the DESI index* (Policy Paper No. 5). Polish Economic Institute.
- Thorsen, T., & Bick, M. (2023). A decade of digital maturity models: Much ado about nothing? *Information Systems and e-Business Management*, 21, 947–976. <https://doi.org/10.1007/s10257-023-00656-w>
- Tiutiunyk, I., Drabek, J., Antoniuk, N., Navickas, V., & Rubanov, P. (2021). The impact of digital transformation on macroeconomic stability: Evidence from EU countries. *Journal of International Studies*, 14(3), 220–234. <https://doi.org/10.14254/2071-8330.2021/14-3/14>
- Tomczyk, Ł., Kielar, I., Daś, A., & Daś, N. (2023). Digital Exclusion and Inclusion in Poland – An Overview of Research and Educational Activities from Recent Decades. In: Tomczyk, Ł., Guillén-Gámez, F.D., Ruiz-Palmero, J., Habibi, A. (eds) *From Digital Divide to Digital Inclusion*. Lecture Notes in Educational Technology. Springer, Singapore. https://doi.org/10.1007/978-981-99-7645-4_20
- Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889–901. <https://doi.org/10.1016/j.jbusres.2019.09.022>
- World Bank. (n.d.a). *E-Government Development Index (EDGI)*. Data 360. https://data360.worldbank.org/en/dataset/UN_EGDI
- World Bank. (n.d.b). *Global Competitiveness Index (GCI) 4.0*. Data 360. https://data360.worldbank.org/en/dataset/WEF_GCI
- World Intellectual Property Organization. (n.d.). *Global Innovation Index*. <https://www.wipo.int/en/web/global-innovation-index>

About the Authors

Jakub Boratyn*, B.A.

Faculty of Management, Department of Entrepreneurship
University of Information Technology and Management in Rzeszów
Sucharskiego 2, 35-025 Rzeszów, Poland
e-mail: jboratyn@wsiz.edu.pl
ORCID: 000-0002-6531-7629

Barbara Kesler, B.A.

Faculty of Economics and Management
Opole University of Technology
Prószkowska 76, 45-758 Opole, Poland
e-mail: b.kesler@student.po.edu.pl
ORCID: 0009-0001-8163-9441

Authors' Contributions

J.B., B.K.: conceptualization; original draft preparation; writing, review and editing; supervision.
All authors have read and agreed to the published version of the manuscript.

AI Declaration Statement

The authors used ChatGPT (OpenAI) to assist with language editing and text refinement. All AI-generated suggestions were reviewed, edited, and verified by the authors, who take full responsibility for the content. No AI tools were used for data analysis, interpretation, or the generation of original ideas.

Acknowledgements and Financial Disclosure

None reported.

Conflict of Interest

The authors declare that the research took place without any commercial or financial relationships that could be construed as a potential conflict of interest.

Copyright and License



This article is published under the terms of the
Creative Commons Attribution (CC BY 4.0) License
<http://creativecommons.org/licenses/by/4.0>

Published by the Krakow University of Economics – Krakow, Poland