Central European Journal of Economic Modelling and Econometrics

Does Sustainability Contribute to Digital Transformation? Evidence from an Executive Survey

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Submitted: 9.12.2025, Accepted: 21.05.2026

Abstract

Design/methodology/approach: Using data from a survey conducted on a sample of executives and managers from companies listed on the Warsaw Stock Exchange, we examine the evolution and synergies between ESG awareness (environmental, social and governance) and digital technology adoption (DTA) over a period of five years (2018-2022). Purpose: Drawing upon stakeholder theory and the concept of Industry 5.0, we investigate the association between the implementation of sustainability and digital technologies. Findings: Findings reveal that DTA is positively associated with 1) ESG awareness, 2) ESG-linked incentives, 3) use of software supporting ESG, and 4) ESG-linked stakeholder satisfaction. Practical implications: The paper offers insights into the link between DTA and sustainability in a less advanced economy, where the use of digital technologies is less prevalent. Originality: We attribute findings to the presence of strong regulatory and stakeholder pressure for sustainability adoption in listed companies which rely on technological support for ESG data collection, reporting, analysis and performance measurement, as well as the synergies between DTA and sustainability.

Keywords: digital technology adoption, digital technologies, environmental, social, governance, ESG, sustainability

JEL Classification: M1, O3

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1 Introduction

Digital technology adoption (DTA) is defined as the adoption of technologies such as automation, digitalization, big data, blockchains, the internet of things (IoT), and artificial intelligence in the company's operation and strategy (Zhang et al., 2024). With its scope and intensity, the process covers all sectors and branches of the economy, impacting operations in industry, services, trade, the health care system, education, or public administration. The implementation of digital technologies constitutes a broader shift beyond its technological transformation (Kraus et al., 2021), as it reshapes processes in companies, enabling more rapid exchange of information supporting decision-making in the areas of finance, production, investments, marketing, and human capital management (Bogers et al., 2022). Existing literature shows that DTA serves as a driver of broader organization change, namely digital transformation (Nadkarni & Prügl, 2021). The use of digital technologies empowers stakeholders while improving diversity and inclusion, providing new opportunities for persons with disabilities, those who are home bound, and people in rural areas, as well as bringing global access to new markets for both employees and consumers (Paul et al., 2024; van Toorn, 2024).

Despite its significant impact regarding how business functions and the mechanisms of digital technology adoption (Bogers et al., 2022), its outcomes and interactions with organizational characteristics remain significantly unexplored. The existing literature follows the view of models that emphasize profitability and shareholder primacy (Ghobakhloo et al., 2022), suggesting a business case for digitalization. Specifically, prior studies focus predominantly on the microeconomic consequences of adoption of digital technology with regard to its role in improving a company's financial performance and increasing firm value. Studies reveal that the adoption of digital technologies strengthens company competitiveness, adding to a better quality of customer service and more effective cooperation with suppliers and other business partners (Dubey et al., 2024). The impact of digital technologies on business models and company functioning also calls for their potential application in the process of transition toward sustainability. Zhang et al. (2023:2) emphasize that "it is urgently needed for businesses to overcome survival challenges and to plan for future development".

Regarding environmental, social, and [corporate] governance (ESG) researchers suggest a myopic view of how technology can contribute to address sustainability concerns, recognizing that "environmental or grand challenges-driven innovation management is hardly implemented in many companies' innovation management" (Meissner et al., 2024:1). Even so, digital technology is expected to mitigate some of the negative impacts of companies on society and the natural environment. This is important given the magnitude of sustainability concerns related to climate change and social inequality in the context of global tensions (George & Schillebeeckx, 2022), with the goal of developing capabilities for innovation in traditional business models and the introduction of sustainable profit structures.

In this paper we draw upon stakeholder theory and the concept of Industry 5.0 to identify the associations between sustainability and digital technology adoption. In particular, unlike prior studies which suggest that DTA contributes to sustainability (George & Schillebeeckx, 2022; Leng et al., 2022; Zhang et al., 2024), we hypothesize a reverse link, suggesting that the implementation of ESG guidelines, consisting of principles formulated at the company level, increases demand for the adoption of digital technologies. We examine the impact of regulatory changes towards mandatory sustainability reporting (Baboukardos et al., 2023), the development of sustainable finance (Macchiavello & Siri, 2022; Safi et al., 2024) and stakeholder pressure (Hall et al., 2014; Parolin et al., 2024) toward addressing socio-environmental concerns. We argue that DTA is an outcome when companies are required to transform their operations into sustainable business models with responsible management practices (Cornell & Shapiro, 2021). This is because the implementation of sustainability in organizations requires the collection and reporting of ESG data (Aluchna & Krawczyńska-Kaczmarek, 2025) followed by the construction of ESG-related KPIs and metrics to analyze a company's impact on society and the natural environment. Harnessing the links between sustainability and DTA, we formulate research hypotheses examining the following questions: 1) whether sustainability drives growth in digital technology adoption, and 2) whether digital technology adoption is related to value for all stakeholders (investors, customers, employees). To address these questions, we investigate the association between the ESG awareness, as measured by the implementation of sustainability within the organization, and digital technologies. We test hypotheses using data derived from a survey conducted on a sample of executives and top managers from 204 companies listed on the Warsaw Stock Exchange, examining the evolution and links between the use of digital technologies and ESG over a period of five years (2018-2022). Our findings reveal that the use of digital technologies is positively associated with 1) the overall level of ESG awareness asserted by executives and top managers, 2) the presence of ESG-linked incentives for executives, 3) the use of software to measure ESG goals, and 4) ESG-linked stakeholder satisfaction. We indicate the role of the demand side for DTA in the form of imposed regulation and stakeholder pressure suggesting that ESG implementation may serve as the driver of innovation and efficient use of resources. Overall, we contribute to existing literature in showing that due to stakeholder scrutiny and regulatory pressure, companies engage in the transition toward sustainable business, which drives demand for the use of digital technologies at the company level. While current research focuses mostly on external pressures (e.g., Corporate Social Responsibility Directive, EU Taxonomy), our findings offers a micro-foundation view of compliance. We emphasize the role of ESG reporting as a driver for broader DTA showing that requirements for sustainability disclosure are internalized into the firm procedures and communication system. Our findings also suggest that implementing ESG principles helps promote digital technology adoption by requiring monitoring what corresponds with arguments by Zhao & Cai (2023) who claim that digital technology adoption fulfill the needs of firm "ESG information disclosure, information management and capital market supervision. This not only enhances the comprehensiveness and timeliness of ESG information disclosure but also improves the efficiency and convenience of ESG information management and operation, thus helping to enhance the ESG practice capability of firms and improve their ESG performance". This evidence suggests that ESG reporting and compliance systems are no longer a separate domain but are integrated in the organizational structure. Such integration adds to the overall process of sustainability transition and may accelerate development of technological infrastructure.

2 ESG and digital technology adoption

2.1 DTA and sustainability

Given the stakeholder pressure (Donaldson & Preston, 1995) and the introduced regulatory changes, firms are required to undertake efforts to lower their negative impact on society and the environment and to ensure sustainable development (Cornell & Shapiro, 2021). According to the Brundtland Commission of 1987, sustainable development is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs, thus calling for inter-generational responsibilities (UN, 1987). Sustainability accounts for increasing the welfare of various stakeholders, addressing the grand challenges including climate change and social inequalities (Ackermann, 2024) as well as supporting the implementation of 17 UN Sustainable Development Goals (SDGs) 2030. It is operationalized into the environmental, social and governance (ESG) metrics on performance and disclosure standards that represent the non-financial effect of a company's operation.

Conceptually, DTA and the implementation of ESG principles into company practice is encompassed within the recently proposed idea of Industry 5.0 (Barata & Kayser, 2024; Ghobakhloo et al., 2024). In contrast to the profit-focused Industry 4.0 concept, its Industry 5.0 successor aims to go beyond efficiency and productivity as the predominant company objectives. Industry 5.0 constitutes an emerging paradigm that incorporates the adoption of digital technologies and promotes human-centricity, socioenvironmental sustainability, and resilience in assuming a positive impact on society (Bregar, 2024). Industry 5.0 is materialized in the use of digital technologies and infrastructure in the workplace as well as private life (Baig & Yadegaridehkordi, 2024; Barata & Kayser, 2024). It is anticipated that DTA may solve broader problems regarding environmental, energy, and social challenges (Barata & Kayser, 2023). Thereby, the concept assumes an active role for industry in providing solutions to social and environmental challenges (Garrido et al., 2024), including the preservation of resources, climate change mitigation and social stability (European Commission, 2024). The idea of Industry 5.0 is expected to contribute to the transition to a sustainable, human-centric and resilient industry (Renda et al., 2022). As a result, Industry 5.0 is not technology-driven but value-driven (Barata & Kayser, 2023).

2.2 ESG data

Some scholars, however, point out that "digital technology is a double-edged sword" (Ding et al., 2024; Dwivedi et al., 2023) which on the one hand empowers ESG practices but on the other hand adversely affects certain social and environmental aspects (Alexopoulos & Cohen, 2016; Cardinali & De Giovanni, 2022). Nevertheless, the majority of analyses suggest an improvement in ESG performance with the support of digital technologies, referring to the need for the collection, analysis and management of non-financial information across organizational processes and value chains (L. Wang & Hou, 2024). The measurement of ESG activities may contribute to the efficient implementation of sustainability in the company management by introducing technology assessment tools which offer a "systematic approach to evaluate the technical feasibility, economic viability, and societal impacts of new technologies and innovation" (Parolin et al., 2024). With sustainability incorporated into strategy, ESG metrics offer key performance indicators and may serve as a benchmark for compensating executives and comparing a firm's non-financial standings versus its peers.

Existing research offers ample evidence regarding the beneficial effects of digital technology uptake and the consequent improvement in ESG performance (George & Schillebeeckx, 2022; J. Wang et al., 2023), contributing to sustainable business practices (Di Vaio et al., 2020). This relationship is noted both for environmental performance (Chen et al., 2023; George et al., 2021) and for social responsibility performance (Zhong et al., 2023). Digital technology adoption enhances internal control and green innovation (Lu, 2024), supports sustainability by empowering stakeholders (D. Wang & Xia, 2024), facilitates inclusion and diversity, provides platforms for dialog between a company and its constituencies, lowers costs and reduces information asymmetry in cooperation between different stakeholders. Leveraging digital technologies results in a greater intensity of relations and interactions between companies and their stakeholders, improving ESG performance and increasing company value. Harnessing prior studies we propose the following hypothesis, H1:

H1: *There is a positive association between ESG awareness and digital technology adoption*

2.3 Sustainability reporting

The use of digital technologies remains crucial from the perspective of the collection and management of ESG information (Haller et al., 2018). However, existing studies have indicated structural limitations underlying the change in business models, showing that ESG activities and disclosure were driven by instrumental motivations for improving the firm's reputation and gaining legitimacy (Mio, 2010). ESG activities and disclosures are required to be precise, based on double materiality including impact materiality and financial materiality, as well as being data-driven (Baumüller & Sopp, 2022). This creates a strong demand for the adoption of digital technologies that are expected to support the sustainability transition strengthened by the regulation on mandatory non-financial reporting (Aluchna & Krawczyńska-Kaczmarek, 2025).

Consequently, the sustainability transition drives DTA via four main channels – data collection, reporting, performance measurement and implementation. Firstly, the use of digital technologies may facilitate the collection of ESG data which extends traditional financial reporting to incorporate information on the company's impact on society and the environment (Chan et al., 2014). Given the multi-dimensional impact of a company on society and the environment, the ESG data required for collection not only covers different dimensions of the company's operational activity but also refers to its performance across the value chain (Tran & Coqueret, 2023).

Secondly, digital technologies prove to be essential for sustainability reporting, which is defined as the communication of ESG performance to the general public and particular stakeholders (Haller et al., 2018). With the support of information systems, companies publish non-financial reports that incorporate verified data and well-constructed indicators that correspond with recognized standards (Irajifar et al., 2023). In line with the regulatory pressure in the form of mandatory reporting legislation, companies are required to develop the ESG data collection and reporting infrastructure, increase the scope of disclosure and improve the quality of communicated data (Aluchna & Krawczyńska-Kaczmarek, 2025; Pizzi et al., 2024). The digital form of the report is expected to increase access to ESG data, whereas the adoption of reporting standards and mandatory assurance increases the credibility of published information. Given the demand which ESG creates for digital technology adoption and the pressure toward sustainability management, we assume that the importance of ESG efficiency (defined as utilizing software to measure ESG goals and implementing digital projects in the ESG area) drives the use of digital technologies. Thus, we formulate the following hypothesis, H2:

H2: *There is a positive association between ESG efficiency and digital technology adoption*

Further, digital technologies may support the measurement of ESG performance with the use of particular metrics and key performance indicators. ESG information that serves as a fundamental source for scoring and ratings (Billio et al., 2021) allows for the comparability of company performance across industry peers and for determining how company reputation and the sector ranking evolve over time. Finally, with the understanding of performance evolution a firm may obtain capabilities to prioritize sustainability activities, integrating them with digital technologies and linking them to corporate strategy (Adams et al., 2016; Bose et al., 2022). ESG analytics and ESG-related KPIs function as an adaptation or learning tool for strategy implementation and strategy-making functions (Gond and Moon, 2011). ESG metrics may be linked to project assessment, promotion or compensation having an impact on leadership, advocacy, corporate culture, control and governance. In sum, the strategic approach to sustainability introduces ESG importance with regard to having ESG policy and linking the CEO's compensation and managerial bonuses to the achievement of ESG goals, so as to incorporate the stakeholder perspective into corporate strategy and contribute to sustainability transition. Recognizing the impact of incentive mechanisms for executives to support the implementation of ESG principles, we formulate the following hypothesis, H3:

H3: *There is a positive association between ESG importance and digital technology adoption*

Sustainability is studied within stakeholder theory which perceives a firm as a collection of stakeholders. Stakeholders are defined as groups, institutions, organizations and individuals who can affect or are affected by the firm in the course of the firm pursuing its goals (Donaldson & Preston, 1995; Freeman & Cavusgil, 1984). In opposition to the narrow notion of the shareholder-primacy perspective ESG extends the group of constituencies the company is responsible to. It suggests the need for the assessment of multi-dimensional performance including social and environmental impact. As a result, companies need to address the expectations of stakeholders which include customers, suppliers, communities, regulators, investors and media (Garcia et al., 2017; Kacperczyk, 2009) balancing financial and non-financial goals for creating sustainable wealth. According to stakeholder theory, the expectations of different constituencies need to be identified, understood, and incorporated in corporate strategy that requires a reorientation of business goals and models as well as the development of KPIs that recognize stakeholder-related metrics for the assessment of executives (Friedman & Miles, 2002). The existing literature documents the development of stakeholder theory to recognize the contextual characteristics of company-stakeholder relations. In particular, the seminal paper by Mitchell et al. (1997) proposes stakeholder salience theory, which rests on the premise that companies should identify and prioritize stakeholders on the basis of their attributes and the urgency of their claims. Confronted with limited resources and capabilities, the strategic approach assumes that companies focus on salient stakeholders and incorporate their expectations by strategically neglecting the demands of other groups.

Recent developments in stakeholder theory elaborate on the conflicting expectations of constituencies. The stakeholder resource-based view (SRBV) (Barney, 2018; Harjoto et al., 2022a) suggests that stakeholders should on the basis of their attributes related to the nature of formulated claims and control over recourses. In order to make profits companies need to have stakeholders with residual claims on profits (Barney, 2018). Stakeholders with access to resources critical to creating value by a company have higher economic bargaining power and are residual claimants as compared to fixed claimant (Harjoto et al., 2022b). Moreover, in line with the concept of stakeholder influence capacity (SIC) (Barnett & Salomon, 2018) firms differ in their ability to identify, understand, and respond to the stakeholder interests and to convert CSR investments into tangible financial benefits.

Industry 5.0 proposes that human-centricity and micro-objectives encompassing the ideas of economic growth are balanced with stakeholder wellbeing (Breque et al., 2021). This requires incorporating stakeholder claims into sustainability management. Put differently, the implementation of ESG principles by companies is driven by the expected benefits of increased investor, customer and employee satisfaction. This link will be supported by the adoption of digital technologies. Therefore, we formulate the following hypothesis, H4:

H4: *There is a positive association between ESG value for stakeholders and digital technology adoption*

H4a: *There is a positive association between ESG value for investors and digital technology adoption*

H4b: *There is a positive association between ESG value for customers and digital technology adoption*

H4c: *There is no association between ESG value for employees and digital technology adoption*

3 Research Design

3.1 Sample and data

We use data collected from a sample of companies listed on the Warsaw Stock Exchange. In this study we use two sources of data – 1) data on digital technology adoption and ESG awareness obtained from the executive survey and 2) information on the overall company characteristics derived from the Refinitiv Eikon/LSEG data base. Firstly, we employ information obtained from the executive survey conducted with the use of Computer Assisted Telephone Interviewing (CATI). Respondents included executives and top managers of sample companies and provided answers to the constructed questionnaire, which covered aspects related to digital technology adoption and ESG awareness. The sample was purposefully constructed to ensure the balanced representation of companies with regard to the company size and sector of operation. Secondly, we collected data on the overall company characteristics on the size, performance, value and ownership structure which were extracted from the Refinitiv Eikon/LSEG base. To depict the evolution of digital technology adoption over time, the questionnaire and Refinitiv Eikon/LSEG data covered three periods – 2018, 2020 and 2022.

3.2 Variables and Measurement

Explained variable

In this study we investigate the relationship between a company's digital technology adoption and its ESG awareness. DTA is measured with the use of a constructed index, and it serves as our primary explained variable. It is constructed based on information extracted from the executive survey. Following prior studies (Castro Benavides et al., 2022; Yeow et al., 2018), we categorize DTA based on the scope and extent of implemented technologies and created infrastructure, as well as activities undertaken. In particular, the questions in the survey questionnaire that were used as a basis for the constructed digital technology adoption index related to four categories (see Table 1), including 1) Strategy: the formulation of company digital strategy, the use of technologies that assist in understanding customers' needs, enhance products and services; 2) Technology: the adoption of digital technologies with identified priorities; 3) Organization: the technical capability to work remotely for back-office functions, remote work policies in place and remote contact with stakeholders; 4) Financing: the construction of the budget for digital initiatives.

Due to rapid technological change and complexity of the issue, significant difficulties in measuring digital maturity and DTA are observed (de Bruin et al., 2005; Ochoa-Urrego & Peña-Reyes, 2021). While attempting to measure DTA, numerous dimensions must be taken into consideration (Teichert, 2019). Based on the dynamic capabilities approach, also Warner & Wäger (2019) suggested that not only technologies themselves must be implemented to achieve high level of digitalization but also strategic and organizational factors as well as internal entrepreneurship play significant role in efficient implementation of change. Therefore, our metric has been based on these 4 pillars.

Respondents were asked to answer multiple questions in these categories according to a given scale.

The index was constructed as the mean of scores obtained across the four given categories on the basis of the following equation:

$$DTA\_index = \frac{Strategy + Technology + Organization + Financing}{4}$$

The simple average was selected to reflect the equal importance of each pillar. The final value representing the advancement of each of the pillars is composed (weighted average) of a set of questions allowing for the evaluation of pillar-wise maturity. Below, a set of questions that were used within a particular pillar are presented. Each pillar is composed of two or three categories which are weighed according to their importance to create a comprehensive and substantial picture of the digital technology adoption level in each company:

– The *Technology* pillar comprises two sets of questions (weights in the brackets): core-technology usage (75%) and niche-technology usage (25%).

Table 1: Components of digital technology adoption index

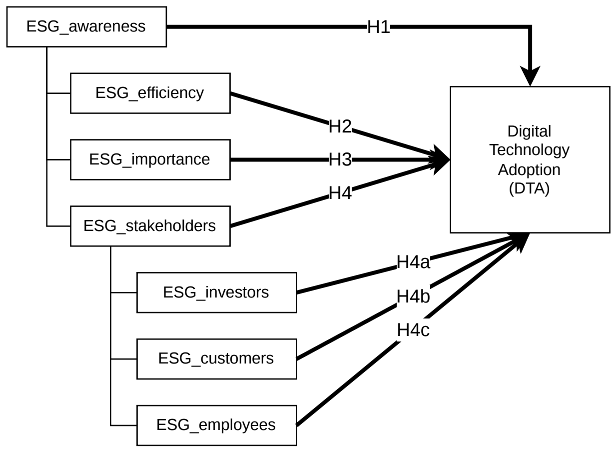
Strategy	Financing	Technology	Organization
– Digital strategy document – Using advanced technologies to understand client needs and improve products and services	– Financing for digital project in front- and back-office	– Implementation of core and niche technologies	– Technical possibility to work remotely for back-office function – Remote work policy in place – Remote contact with stakeholders

- The *Financing* pillar is a composite of questions related to spending on digitalizing the front office (50%) and back office (50%).
- The *Organization* pillar covers the broader set of questions that link to the possibility of remote work (50%), policy regarding remote work (25%) and remote contacts with company stakeholders (25%).
- The *Strategy* pillar refers to questions concerning the accommodation of digital strategy (50%), the use of technologies for customer needs evaluation (25%), and the use of technologies for improving products and services (25%).

The range of the answers for each question was set to 0 and 1, where 0 referred to the lowest advancement in the pillar and 1 to the highest. For each company, the value of every pillar was calculated as the weighted average of answers. Exact survey questions can be found in Appendix.

Explanatory and control variables
To investigate the ESG awareness of sample companies we use information derived from the executive survey in which respondents were asked to evaluate the company's progress in its ESG implementation and its link with adoption of digital technology. The questions covered the following (always simple average): 1) ESG Importance: having an ESG policy and linking the CEO's compensation and managerial bonuses to the achievement of ESG goals, including the adoption of ESG-linked CEO compensation and an ESG-linked CEO bonus at the executive and managerial level; 2) ESG Efficiency: utilizing software to measure ESG goals, digitization projects in the ESG area; 3) ESG Value for Stakeholders: the satisfaction of stakeholders (investors, customers, employees) depends on the achievement of ESG goals, which means that there is a link between ESG principles and stakeholder satisfaction

Figure 1: Conceptual framework



Notes: On the left hand side the hierarchical structure of explanatory variables used in the study is presented.

(investors, customers, employees), as well as the effect of ESG implementation for fund-raising for new projects. Respondents were asked to answer questions according to a given scale. We provide the survey to show how the research questions and the survey questions were aligned in the Table in Appendix. In the last column of Table in Appendix we reveal the used scale which served as the reference point to calculate the ESG variable values.

In the second stage, based on the empirical material collected from the questionnaire, we constructed the overall ESG_awareness as the means of scores obtained across the three given categories on the basis of the following equation:

$$ESG\_awareness = \frac{Importance + Efficiency + Value\ for\ Stakeholders}{3}$$

Figure 1 summarizes the conceptual framework with formulated hypotheses.

For econometric modelling, we include several control variables, such as company size (measured as the natural logarithm of assets; Ln_assets), firm financial performance (measured as return of assets, ROA), proxy of Tobin's Q (measured as ratio of market value to book value, Q), inclusion in one of the main WSE indices (WIG), and ownership concentration (measured as the percentage of shares controlled by the largest shareholder, First). In order to assess reliability of the constructed indices we calculated Cronbach's alpha reliability coefficient. For our first index of DTA Cronbach's alpha was estimated at 0.82, for ESG_awareness Cronbach's alpha was estimated at 0.77, whereas for the aggregated variable ESG_stakeholder we obtained Cronbach's alpha at 0.73. All estimates are above 0.7 what we interpret as evidence of reliability of our measures (Mohsen & Reg, 2011).

3.3 Methodology

Our sample is a balanced panel of answers from the executive survey with a total of 615 observations. We construct our models with the explained variables depicting DTA and the explanatory variable of ESG awareness over three points of time (2018, 2020, 2022), including control variables. We estimate three linear regression panel models with fixed effects according to the following equations:

$$DTA\_Index = f(ESG\_awareness, lnAssets, ROA, Q, First, WIG)$$

$$DTA\_Index = f(ESG\_efficiency, ESG\_importance, ESG\_stakeholders, lnAssets, ROA, Q, First, WIG)$$

$$DTA\_Index = f(ESG\_efficiency, ESG\_importance, ESG\_customers, ESG\_investors, ESG\_employees, lnAssets, ROA, Q, First, WIG)$$

These models estimate the same relation on different levels of granularity (ESG_awareness = (ESG_efficiency + ESG_importance + ESG_stakeholders)/3, whereas ESG_stakeholders = (ESG_customers, ESG_investors, ESG_employees)/3; the consecutive equations remove constraints on relative weight of ESG awareness components). We do not include the variable of the sector of operation since we use the fixed effects panel model, grouped by company to control for individual company effects. Therefore, the sector of operation is fully incorporated in our models. The adoption of the fixed effect approach also allows us to capture the internal company variability of the company size, financial performance, company value, ownership concentration and the presence in WIG index.

The adopted methodology reveals some limitations due to the fact that that key variables are executive-reported. We recognize that common-method variance and social desirability bias are possible. Such limitations may particularly refer to the theme of ESG-related items as executive may express excessively optimistic or legitimacy driven aspirational view on this topic. Yet, due to the lack of information on digital technology, adaptation collection data with the use of survey is the most appropriate source.

3.4 Descriptive Statistics

We provide descriptive statistics and correlation matrix to present the overall characteristics of the sample companies in Table 2.

As shown in Table 2, DTA_index is estimated at 0.51 on average, whereas ESG_awareness equals on average 0.66. According to the calculation procedure for

Table 2: Summary statistics of the analyzed data

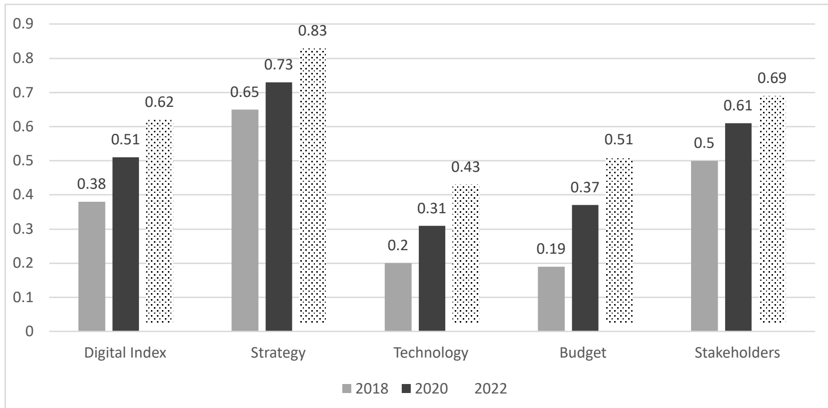
a. Central tendency and dispersion

	Mean	SD
DTA_index	0.51	0.19
ESG_awareness	0.66	0.28
ESG_efficiency	0.75	0.25
ESG_importance	0.31	0.22
ESG_stakeholders	0.36	0.28
Ln_assets	0.60	0.18
ROA	0.66	0.28
Q	0.61	0.27
First	0.68	0.35
WIG	0.69	0.37

b. Pearson correlation matrix

	DTA_index	ESG_awareness	ESG_efficiency	ESG_importance	ESG_stakeholders	Ln_assets	ROA	Q	First
DTA_index									
ESG_awareness	0.46*								
ESG_efficiency	0.50*	0.77*							
ESG_importance	0.46*	0.82*	0.54*						
ESG_stakeholders	0.55*	0.83*	0.53*	0.54					
Ln_assets	0.16*	0.09	0.09	0.06	0.15*				
ROA	0.01	-0.01	-0.01	-0.04	0.05	0.17			
Q	0.05	0.01	0.01	-0.01	0.002	-0.04	0.09		
First	0.05	0.03	0.03	0.08	-0.04	0.22*	-0.03	-0.11	
WIG	0.16*	0.14*	0.14*	0.09	0.15*	0.57*	0.12*	0.03	0.06

Figure 2: The evolution of the digital technology adoption index, 2018-2022



both variables the maximum possible level is 1. All three measures of ESG-linked stakeholder satisfaction reveal relatively high values with 0.75 for ESG_efficiency followed by 0.31 for ESG_importance and 0.36 for ESG_stakeholder measure. We note the correlation between the constructed ESG variables and the digital technology adoption measure. In addition, there are links between the company presence in the WIG indices and the ESG variables, as well as between presence in the WIG indices and digital technology adoption measures, respectively.
In Figure 2 we provide the evolution of the digital technology adoption index over the analyzed period with a breakdown into the four identified components.
As shown in Figure 2, we note a steady increase in the overall index of digital technology adoption, from 0.38 in 2018 to 0.62 in 2022. The data also reveal an increase across all categories of the index – 1) the formulation of company digital strategy, 2) the adoption of digital technologies with identified priorities in the digital technology adoption, 3) the construction of the budget for digital initiatives and 4) the use the technologies that assist in understanding clients' needs, enhance products and services, and facilitate communication with stakeholders.

4 Results and Discussion

In the analysis we determined the appropriate model specification and discriminated between fixed, random effects and pool model. Firstly, to assess whether a pooled OLS specification is appropriate relative to the fixed effects model, F-tests for individual effects were conducted across all model specifications. In each case, the null hypothesis that all individual effects are jointly equal to zero is strongly rejected. The test statistics are F = 2.10 (p = 0.0000), F = 4.00 (p = 0.0000), and F = 2.11 (p = 0.0000).

These results indicate the presence of significant unobserved individual heterogeneity, supporting the use of the fixed effects model over pooled OLS in all specifications.
Secondly, we conducted the Breusch-Pagan Lagrange Multiplier tests for random effects to compare pooled OLS with the random effects specification across all model variants. In each case, the null hypothesis that the variance of the panel-level effect is equal to zero (Var(u) = 0) is strongly rejected. The test statistics are χ^2= 40.36, χ^2 = 34.91, and χ^2 = 36.32, all with p-values of 0.0000. These results provide strong evidence of significant unobserved panel-level heterogeneity, indicating that the random effects model is preferred over pooled OLS in all specifications.
Thirdly, to determine between fixed effect model and random effects, we conducted Hausman tests. The results consistently indicate statistically significant differences between the fixed effects and random effects estimators across all model specifications. In particular, the test statistics amount to $\chi^2 = 15.37$ ($p = 0.0176$), $\chi^2 = 22.28$ ($p = 0.0044$) and $\chi^2 = 30.04$ (p = 0.0008). In each case, the null hypothesis that the differences in coefficients are not systematic is rejected, implying that the random effects estimator is inconsistent. Therefore, the fixed effects model is preferred in all specifications, and the subsequent analysis is based on the fixed effects approach.
Given the results of the above tests below we report results of fixed effect model as our main results followed by robustness test of random effects model and pool model. The results of the fixed effects panel models are presented in Table 3.
As shown in Table 3 in the second column, firstly we test hypothesis H1, which assumes that there is a positive association between DTA and ESG awareness. With this hypothesis we leverage on the interplay between the growing shift towards sustainability that induces demand for technological support in the form of digital solutions and infrastructure. The results, based on the responses from the executive survey, are reported in the second column of Table 3 and reveal a positive link between the DTA index and the ESG awareness index. Therefore, hypothesis H1 is supported. We follow this by testing hypothesis H2. The results in the third column of Table 3 indicate that there is a positive association between the digital technology adoption index and ESG_efficiency supporting hypothesis H2.
Next, we test hypothesis H3, which states that there is a positive association between digital technology adoption and ESG_importance in the organization, perceived as the existence of ESG policy and links between CEO compensation (and managerial bonuses) and the achievement of ESG goals. The results show that, in line with our assumption, there is a positive association between DTA and ESG_importance. Hence, hypothesis H3 is supported. Confronting results from the second and third column shows that out of the components of ESG_awareness the strongest effect is noted for ESG_efficiency.
Finally, as shown in Table 3 in the third column, there is a positive association between adoption of digital technology and ESG value for stakeholders. Therefore, we state that hypothesis H4 is confirmed. Yet, results of the detailed analysis reported in the fourth column in Table 3 show that the effect is driven by the association between

Table 3: Regression results – fixed effects

	DTA_Index	DTA_Index	DTA_Index
ESG_awareness	0.31^{***} (0.04)		
ESG_efficiency		0.16^{***} (0.04)	0.16^{***} (0.04)
ESG_importance		0.08^{**} (0.03)	0.08^{**} (0.03)
ESG_stakeholders		0.07^{*} (0.03)	
ESG_investors			-0.04 (0.03)
ESG_customers			0.04^{*} (0.03)
ESG_employees			0.02 (0.02)
Ln_assets	0.03^{*} (0.01)	0.03^{*} (0.01)	0.03^{*} (0.01)
ROA	-0.0002 (0.001)	-0.0001 (0.001)	-0.0001 (0.001)
Q	0.001 (0.001)	0.0004 (0.004)	0.0004 (0.004)
First	0.002^{*} (0.0001)	0.002^{*} (0.001)	0.003^{*} (0.001)
WIG	0.05^{**} (0.03)	0.05^{**} (0.03)	$0.04'$ (0.03)
Cons	0.06 (0.07)	0.06^{*} (0.08)	0.05 (0.04)
R^2 within	0.23	0.23	0.24
R^2 between	0.29	0.28	0.25
R^2 overall	0.27	0.26	0.24

Notes: Robust standard error in parentheses, significance level ***0.001, **0.01; * 0.05; '0.1; standard deviation in parentheses.

Table 4: Robustness tests – random effects

	DTA_Index	DTA_Index	DTA_Index
ESG_awareness	0.37^{***} (0.02)		
ESG_efficiency		0.167^{***} (0.03)	0.18^{***} (0.04)
ESG_importance		0.08^{**} (0.03)	0.09^{***} (0.022)
ESG_stakeholders		0.08^{***} (0.02)	
ESG_investors			-0.01 (0.02)
ESG_customers			0.09^{***} (0.03)
ESG_employees			0.03^{*} (0.02)
Ln_assets	0.004 (0.004)	0.0001 (0.001)	0.01^{*} (0.01)
ROA	0.0001 (0.001)	0.0001 (0.004)	0.0001 (0.001)
Q	0.005 (0.004)	0.0001 (0.004)	0.001 (0.001)
First	0.001 (0.001)	0.001 (0.001)	0.005^{*} (0.001)
WIG	0.03 (0.02)	0.03^{*} (0.0183)	0.03^{*} (0.02)
Cons	0.2^{***} (0.03)	0.2^{***} (0.03)	0.01^{**} (0.04)
R^2 within	0.2	0.2	0.2
R^2 between	0.47	0.49	0.48
R^2 overall	0.37	0.38	0.38

ESG value for customers and DTA (support for hypothesis H4b), while no link is found for ESG value for investors (no support for hypothesis H4a) and ESG value for employees (no support for hypothesis H4c).

In order to assess robustness of the results obtained we performed additional random effects models and pooled models estimations. The results of this analysis are presented in Tables 4 and 5.

As shown in Tables 4 and 5 the results of robustness tests are consistent with the previous findings and support our base models. They indicate a positive association between DTA and ESG awareness (supporting H1), a positive link between DTA and ESG_efficiency (supporting H2), a positive association between DTA and ESG_importance (supporting H3) and a positive association between DTA and the overall ESG value for stakeholders (supporting H3). Out of stakeholders the positive and statistically significant results are driven by the effect for customers (supporting

Table 5: Robustness tests – pooled model

	DTA_Index	DTA_Index	DTA_Index
ESG_awareness	0.39^{***} (0.02)		
ESG_efficiency		0.15^{***} (0.03)	0.16^{***} (0.04)
ESG_importance		0.07^{**} (0.02)	0.08^{***} (0.02)
ESG_stakeholders		0.17^{***} (0.02)	
ESG_investors			0.003 (0.02)
ESG_customers			0.011^{***} (0.02)
ESG_employees			0.03^{*} (0.02)
Ln_assets	0.004 (0.004)	0.004 (0.004)	0.005 (0.004)
ROA	0.0001 (0.001)	−0.0001 (0.004)	0.0001 (0.001)
Q	0.005 (0.004)	0.0001 (0.004)	0.001 (0.001)
First	0.001 (0.003)	0.001 (0.001)	0.001 (0.001)
WIG	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)
Cons	0.2^{***} (0.03)	0.2^{***} (0.03)	$0.06'$ (0.04)
R^2	0.37	0.38	0.38

Table 6: Summary of results

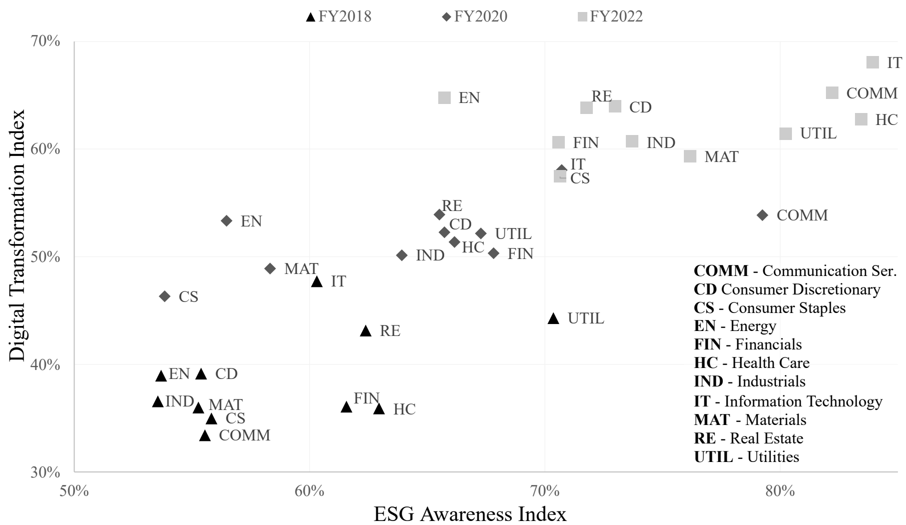
Hypothesis	Assumption of positive association between	Result
H1	ESG awareness and DTA	Supported
H2	ESG efficiency and DTA	Supported
H3	ESG importance and DTA	Supported
H4	ESG value for stakeholders and DTA	Supported
H4a	ESG value for investors and DTA	Not supported
H4b	ESG value for customers and DTA	Supported
H4c	ESG value for employees and DTA	Not supported

H4b), while no statistically significant results are noted for investors and employees. Table 6 summarizes the results in relations to formulated hypotheses.
Finally, we analyze the link between digital technology adoption and ESG awareness, classified according to the year of observation, together with the sector of operation. The results are presented in Figure 3.
Consistent with the result of the linear regression, Figure 3 shows the link between the ESG awareness index and the digital technology adoption index. Secondly, there are sectoral differences with regard to the observed association – the strongest relations are noted for utilities, IT, health care and real estate. Thirdly, Figure 3 also depicts a growth trend for the identified link – the magnitude of the link between the ESG awareness index and the digital technology adoption index moves upwards and to the right, suggesting an increase of both dimensions over the analyzed period.

5 Discussion and conclusions

Our goal is to fill this gap in existing literature and to examine the associations between sustainability and digital technology adoption. In contrast to prior studies that suggest that DTA contributes to sustainability, we argue that the implementation of environmental, social and governance (ESG) principles at the company level increases demand for the use of digital technologies. The results contribute to the existing literature in two ways revealing 1) the identified direction of the relationship between ESG awareness and digital technology adoption and 2) the identified breakdown of stakeholder expectation channel.
Firstly, the results emphasize the role of ESG reporting in creating demand for the use of digital technologies. We argue that the sustainability transition requires digital technology adoption across four main channels – data collection, reporting, performance measurement and implementation. Driven by increased regulatory pressure and stakeholder influence, companies are collecting ESG data which extends

Figure 3: The link between ESG awareness index and digital technology adoption index, by year and sector



beyond traditional financial reporting by communicating non-financial information about their impacts on society and the environment (Atanasov, 2023; Tran & Coqueret, 2023). The use of digital technologies is driven by the growing requirements of sustainability reporting (Haller et al., 2018) and the need for measurement of ESG performance with the use of particular metrics, key performance indicators, ESG scoring and ratings (Billio et al., 2021; Parolin et al., 2024).

Our results suggest that incorporating stakeholders' expectations into company operations increases demand for the use of digital technologies. Since companies need to address the expectations of stakeholders (Donaldson & Preston, 1995; Freeman & Cavusgil, 1984) that include customers, suppliers, communities, regulators, investors and media (Garcia et al., 2017; Kacperczyk, 2009), they need to balance financial and non-financial goals for creating sustainable wealth. Adjusting corporate strategy to create value for stakeholders creates additional needs for digital technologies which facilitate prioritizing sustainability activities (Parolin et al., 2024), integrating them with company operations and aligning them with corporate assessment (Adams et al., 2016; Bose et al., 2022).

The study shifts the perspective toward reflexive complementarity as we demonstrate that DTA is not just a precursor to ESG, but that a developed ESG governance infrastructure characterized by executive awareness and incentive alignment may act as a catalyst for digital investment. The efforts to increase ESG transparency is identified as a driver for broader adoption of digital technology and it represents that principles for sustainability disclosure are internalized into the firm procedures. Thereby, in this paper we extend the research on sustainability and digital technology adoption. Our evidence adds to the research stream on the concept of Industry 5.0 that goes beyond the efficiency and productivity paradigm as the dominant firm goals (Barata & Kayser, 2024; Ghobakhloo et al., 2024) and promotes human-centricity, socioenvironmental sustainability, and resilience (Bregar, 2024). Put differently, "Industry 5.0 represents a systemic transformation that goes beyond solely economic and manufacturing ramifications and has a profound impact on civil society, governance structures, and human identity" (Garrido et al., 2024). In proposing a framework for the coexistence of people and machines (Vogt, 2021), Industry 5.0 offers potential synergies between the use of digital technologies and the implementation of sustainability principles. We call for further research in this field and encourage researchers to identify associations between technology and organizations' efforts for improved financial and non-financial performance.

Secondly, the paper identifies the breakdown of stakeholder-channel and offers the granular evidence of how ESG drives tech adoption. By isolating ESG-linked stakeholder satisfaction we show that DTA is a strategic response primarily to customer demands and to lesser extend is motivated by expectations of investors and employees. From the theoretical standpoint, this result could serve as an initial step to addressing the limitations of stakeholder theory and the concept of creating value for stakeholders. Specifically, while suggesting the importance of the relationships between companies and their constituencies (Donaldson & Preston, 1995; Freeman & Cavusgil, 1984), stakeholder theory does not elaborate on the shortcomings of companies with regard to expertise, resources or strategic capabilities in understanding and incorporating stakeholder demands. In addition, there are potential conflicts arising between emerging stakeholder competing claims (Harjoto et al., 2022c; Mitchell et al., 1997), constrained company resources and the need to focus on those constituencies who remain in a position to exert the most significant influence upon the company. Moreover, as argued by Hall et al. (2014) there is a difference in risk perception between primary and secondary stakeholders in the context of innovating firms what may lead to their engagement or resistance in relations in the company.

Thus, harnessing the theoretical underpinning of stakeholder theory with its recent development including the concept of stakeholder salience, stakeholder competing claims and stakeholder strategic capacity, our results suggest distinguishing between formal ESG in the form of company policy and adopted organizational rules versus ESG impact in the form of value for different stakeholders. This distinction suggest needs for developing theory to conceptualize sustainability application at the company level (Martiny et al., 2024). It also offers new insights for methodology of measuring ESG awareness, performance and impact (Rawhouser et al., 2019).

Our study offers implications for policy and managerial practice. The evidence may be particularly useful for explaining the links between sustainability and DTA in less advanced countries. We employ the survey results from Polish companies that are classified as less advanced in terms of digital technology adoption – according to the Digital Economy and Society Index (DESI) published by the European Commission, Poland is ranked in 24$^{\text{th}}$ position (out of 27) with regard to digital performance (European Commission, 2023). Despite this, the sustainability transition is imposed with a series of mandatory EU regulations of CSRD, Taxonomy, Sustainable Finance and the European Green Deal. Therefore from the perspective policy implications, we emphasize the importance of the demand side for digital technology adoption in the form of imposed regulation and stakeholder pressure suggesting that ESG implementation may serve as the driver of innovation and efficient use of resources. In addition, the positive effects are relevant for companies operating in context of in a less advanced economy characterized with less prevalent use of digital technologies. As companies are facing pressure to adopt sustainability-related legislation, sustainability is becoming a driver to further digital technology adoption in order to support the process of ESG data collection and reporting, followed by impact measurement and strategic prioritizing.

Our study also offers managerial implications which potentially could be of interest for the international audience. While in the process of products, services, and processes innovation companies are required to adjust coordination, information processing, and resource allocation (Rauter et al., 2023), these changes put additional pressure on companies facing limited organizational resources and operating in less advanced economies. Put differently when financially constrained but pressured by institutional framework companies engage rather in exploitative than explorative activity mobilizing their organizational slack to use digital technologies (Depino-Besada et al., 2024). Thus, the evidence from Polish companies shows that there are synergies between sustainability and digitalization (Lu et al., 2024) suggesting that ESG can enhance business model innovation (Marnoto et al., 2024). Overall, the integration of sustainability and digitalization contributes to boosting the modernization and competitiveness (Fan et al., 2024). We view the ESG-DT synergies as the support for a practical pathway to strengthen companies operating in a less advanced economy.

While our study offers important insights to help understand the links between sustainability and digital technology adoption, it also reveals some limitations. Firstly, we rely on data from an executive survey on the statements of executives and top managers, which may color the objectivity of the information obtained. Secondly, we use a single country sample that constrains us in testing interaction effects and does not allow us to examine the impact of the institutional context. Finally, the data covers a relatively short period, with observations being performed in three specific years, i.e. 2018, 2020, 2022. We call for further studies which could adopt longitudinal data to identify the evolution of the associations between digital technology adoption and sustainability.

Acknowledgements

This paper was prepared within the Polish National Science Center (NCN) OPUS "Sustainability decoupling in light of CSRD. Exploring policy-practice and means-ends gaps", no. UMO-2024/53/B/HS4/01206.

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A Survey questionnaire (2018, 2020, 2022)

1. Please assess the level of use of the following technologies in your company (on a scale of 0-5, where 0 is no use, 1 – technology in the testing phase – pilot, 2 – implemented single solutions, 3 – technology used in about half of the processes, where could be implemented in a given area, 4 – technology used in most processes in a given area, where it could be implemented, 5 – technology is the basis of work in a given area – we do not see the possibility of further important implementations at the moment):

Cloud computing
AI
Blockchain
Quantum computers
Robotics
Machine learning
Virtual reality
Metaverse
IoT/Edge computing
5G
Business Intelligence
Digital twin
Mobile/omnichannel

2. Please think about expenditures on new projects in your company – what part of these projects (in financial terms) is related to digital transformation?

Total
Digital transformation projects
– front office (customer relations)
– back office (operations)

3. Please indicate the priority technologies in the field of digital transformation in your company

Cloud computing
AI
Blockchain
Quantum computers
Robotics
Machine learning
Virtual reality
Metaverse
IoT/Edge computing
5G
Business Intelligence
Digital twin
Mobile/omnichannel

4. Please rate the percentage of work performed remotely by employees outside the company/client's premises (0-25%, 25-50%, 50%-75%, 75%-100%)

Sales (front-office)
Customer service

HR and recruitment
Marketing
Product/services management
IT
Finance and accounting
Procurement
Legal department
Other back-office
Production
R&D
Services for customers

5. Please assess the percentage of work potentially (due to technological possibilities) could be performed remotely by employees outside the company/client's premises (0-25%, 25-50%, 50%-75%, 75%-100%)

Sales (front-office)
Customer service
HR and recruitment
Marketing
Product/services management
IT
Finance and accounting
Procurement
Legal department
Other back-office
Production
R&D
Services for customers

6. What percentage of contacts take place via remote channels (0-25%, 25-50%, 50%-75%, 75%-100%)

with customers
with suppliers
with employees
with other contractors
with investors
with NGOs
with communities

7. Do you use the following technologies to understand clients' needs?

Cloud computing

AI
Blockchain
Quantum computers
Robotics
Machine learning
Virtual reality
Metaverse
IoT/Edge computing
5G
Business Intelligence
Digital twin
Mobile/omnichannel

8. Do you use the following technologies to develop and improve products and services?

Cloud computing
AI
Blockchain
Quantum computers
Robotics
Machine learning
Virtual reality
Metaverse
IoT/Edge computing
5G
Business Intelligence
Digital twin
Mobile/omnichannel

9. Does the following factors depend on the achievement of ESG objectives:

CEO compensation
middle management compensation
employee job satisfaction
fund raising
investors' satisfaction
clients' satisfaction

10. Please think about expenditures on new projects in your company - what part of these projects (in financial terms) is related to ESG?

Total
Related to projects on

– environment
– society
– corporate governance
– ESG and digitalization

11. To what extent do you use digital technologies to collect ESG data

Environmental
Social
Governance