

TECHNOLOGY-DRIVEN SUSTAINABILITY: THE IMPACT OF DIGITALIZATION ON ESG RATINGS OF LARGE COMPANIES

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Abstract. This study investigates the relationship between digitalization and ESG performance in DAX 40 companies by combining correlation analysis with regression models that include firm-level controls. While bivariate correlations indicate a positive association between digitalization and the environmental and social components of ESG, these effects dissipate once market capitalization and other firm characteristics are accounted for. This discrepancy suggests that the initial correlations reflect structural firm attributes rather than an independent influence of digital transformation. Regression results show that firm size remains the strongest predictor of ESG performance, whereas digitalization exhibits limited explanatory power when considered in a multivariate context. Furthermore, the magnitude of the estimated effects is economically modest, indicating that digitalization contributes only marginally to substantive sustainability improvements. These findings imply that digital tools alone do not drive higher ESG outcomes; instead, they function as complementary enablers embedded within broader resource, governance, and regulatory conditions. The study contributes to the literature by clarifying the boundary conditions under which digitalization affects ESG performance and by highlighting the need for stronger theoretical and empirical differentiation between statistical associations and economically meaningful effects.

Keywords: digitization, ESG performance, sustainability, corporate reporting, DAX 40, Big Data, AI, blockchain, governance, social responsibility.

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1. Introduction

Sustainability and digitalisation have become two transformative forces reshaping corporate strategy, decision-making, and reporting practices in recent years. Companies are increasingly expected to create long-term value by aligning economic success with environmental and social responsibility (Eccles et al., 2014; Lei et al., 2024; Fülöp & Cifuentes-Faura, 2025). Digital transformation plays a central enabling role in this shift, as digital tools have the potential to enhance data quality, transparency, and accountability in corporate sustainability practices (Pizzi et al., 2024; Qing & Jin, 2023). Against this backdrop, organisations must integrate sustainability and digitalisation into their strategic planning to remain competitive in an evolving regulatory and market environment (Grybauskas et al., 2022; Eriandani & Winarno, 2023).

The corporate sustainability landscape is simultaneously being reshaped by policy frameworks and technological advances. The United Nations Sustainable Development Goals (United Nations [UN], 2015) provide the overarching global agenda for responsible business conduct, while the European Union's Corporate Sustainability Reporting Directive (CSRD) mandates more comprehensive and digitally enabled sustainability disclosure. This regulatory shift directly affects German listed firms, including DAX 40 companies, which are among the first required to implement structured digital sustainability reporting formats such as ESEF and digital tagging (Deutsches Rechnungslegungs Standards Committee, 2023). Digitalisation is also transforming corporate reporting through the use of AI, blockchain, and big data, promising enhanced reliability, comparability, and efficiency in sustainability disclosures (Rane et al., 2023; Antwi et al., 2024; Bin-Nashwan et al., 2025; Fülöp & Cifuentes-Faura, 2025). As KPMG (2024) highlights, data-driven solutions increase the precision and traceability of non-financial reporting.

Although the importance of sustainability and digitalisation is well acknowledged (Ghobakhloo et al., 2021), existing research addresses these areas largely in isolation. Prior studies predominantly focus either on sustainability reporting and ESG disclosure practices (Christensen et al., 2021) or on digitalisation within accounting and financial processes (Möller, 2023, 2025), often neglecting their intersection. Recent practitioner reports (e.g., Reppmann et al., 2024; KPMG, 2024) emphasise that digital tools are crucial for meeting regulatory expectations for transparency and accuracy, yet academic research has not sufficiently examined how digitalisation influences ESG performance outcomes. In particular, the mechanisms through which digitalisation affects ESG ratings, and whether it serves as a catalyst for sustainability performance or merely an efficiency-enhancing tool, remain underexplored. Furthermore, inconsistent standardisation of ESG metrics and their integration into digital reporting systems poses ongoing challenges (Dai et al., 2024; Busch et al., 2016; Fülöp, 2025). These gaps demonstrate the need for empirical evidence on how digital transformation shapes ESG results in practice especially in a highly regulated context such as Germany, where the CSRD imposes early and strict compliance requirements.

This study addresses these gaps by investigating whether, and to what extent, digitalisation supports improvements in ESG performance among German DAX 40 companies. Recognising that digital technologies could affect ESG outcomes through multiple pathways such as enhanced data management, increased transparency, automated compliance, and improved stakeholder communication the analysis explores both the enabling role and potential limitations of digitalisation in driving sustainability outcomes. Accordingly, the study is guided by the following research questions:

- RQ1:** *To what extent does digitalisation influence corporate ESG performance, particularly regarding transparency, comparability, and sustainability outcomes?*
- RQ2:** *Through which organisational mechanisms can digital transformation act as an enabler of sustainability performance and support progress towards the SDGs?*

By examining these questions, this study contributes to current research in three ways. First, it integrates the domains of digitalisation and sustainability, offering a holistic perspective on their interplay in corporate reporting and performance an area that has received limited attention. Second, it empirically evaluates the relationship between digitalisation

and ESG ratings within the German regulatory context, thereby clarifying whether digital transformation is a meaningful driver of sustainability or primarily an operational tool. Third, the study offers practical and policy-relevant insights that can support organisations and regulators in designing effective digital sustainability strategies. The remainder of the paper is structured as follows: Section 2 reviews the theoretical foundations and prior research to define the research gap in detail. Section 3 outlines the research design and methodology. Section 4 presents the empirical results and discusses their implications for theory and practice. Section 5 concludes the study and highlights avenues for future research.

2. Theoretical background

Sustainability is a central component of modern corporate management and is viewed as a strategic imperative (Schaltegger & Burritt, 2018). Companies are increasingly required to integrate environmental, social and economic aspects into their business strategy to remain competitive in the long term (Porter & Kramer, 2011). The United Nations Sustainable Development Goals (SDGs) provide a global framework for sustainable business practices and invite companies to make their economic activities environmentally and socially responsible (UN, 2015).

The ESG (Environmental, Social, Governance) framework guides companies in sustainable management and investment decisions, but the lack of uniform international standards creates comparability challenges (Bloomberg Intelligence, 2023; Deka et al., 2023). ESG aspects have become a primary research focus, particularly regarding digital transformation, as sustainability practices increasingly attract attention from investors, policymakers, and businesses (Wang et al., 2023; Lu et al., 2024). Digitization, in turn, fosters new value creation, efficiency, and transparency, supporting ESG strategies (Fang et al., 2023).

ESG performance, which describes a company's ability to integrate environmental, social and governance criteria into its business strategy, has been the subject of extensive research. The findings consistently show a positive correlation between high ESG performance and financial stability, long-term value creation, and risk minimization (Fu & Li, 2023). Companies with better ESG scores tend to have lower capital costs, higher investment attractiveness and stronger market reputations (Eriandani & Winarno, 2023). This reassuring correlation between ESG and financial performance underscores that sustainability is not just a moral imperative, but also a sound financial strategy.

Digital technologies directly support ESG strategies by improving governance quality, promoting social responsibility, and driving green innovation (Lu et al., 2024; Zhao & Cai, 2023). They reduce information asymmetries, enhance corporate management, and strengthen governance structures (Wang & Xia, 2024). Digital platforms improve stakeholder communication, expanding social engagement (Fu & Li, 2023), while in the environmental sector, they help minimize ecological footprints and optimize sustainable production (Lu et al., 2024). Particularly in regulated industries, digital disclosure enhances compliance and transparency (Tan et al., 2025).

For large companies, digital transformation significantly impacts ESG performance. A study found that 82.5% of DAX 40 firms disclose ESG ratings, leading to higher share prices and

reputational benefits (Banke et al., 2022). Digitalization improves supply chain transparency, operational efficiency, and ESG compliance, enhancing resilience (Zhang & Huang, 2024). Additionally, companies with substantial digital maturity and ESG strategies gain better capital market conditions and investor appeal (Wang & Xia, 2024).

Stakeholder expectations, especially from investors and consumers, drive this shift. Transparent, data-driven ESG strategies enhance reputation security and prepare companies for regulatory risks (Karwowski & Raulinajtys-Grzybek, 2021). Digital transformation boosts ESG ratings and strengthens market performance and long-term sustainability.

Large companies, particularly DAX firms, play a central role in driving regulatory sustainability requirements. The Corporate Sustainability Reporting Directive (CSRD), in effect from January 5, 2023, mandates extensive ESG disclosures for around 50,000 companies, primarily influenced by the practices of these industry leaders. Replacing the Non-Financial Reporting Directive (NFRD), the CSRD aligns with the EU taxonomy, which classifies sustainable economic activities (EU, 2022). Reporting follows international standards such as GRI and SASB guidelines, while the European Sustainability Reporting Standard (ESRS) enhances comparability and transparency (Global Reporting Initiative [GRI], 2021; Bannier et al., 2023). The CSRD significantly impacts sustainability reporting by mandating extensive ESG disclosures, aligning with the EU taxonomy, and enhancing comparability and transparency through the ESRS, all of which should leave the audience with a comprehensive understanding of its influence.

Beyond financial aspects, sustainability reporting includes environmental, social, and governance (ESG) factors, often assessed by rating agencies like MSCI and Sustainalytics, despite methodological differences (Christensen et al., 2021; Driessen, 2021). Voluntary ESG reporting allows companies to position themselves as responsible actors but leads to inconsistencies, complicating comparability (Herzig & Pianowski, 2022; Quick & Knocinski, 2006). As a response, many firms adhere to standardized frameworks like GRI, widely used since 2002 (Quick & Knocinski, 2006). A KPMG study confirms that over 75% of G250 companies rely on GRI for ESG reporting, aligning strategies and future objectives (KPMG, 2022a). Though not mandatory, standardized reporting enhances transparency and comparability, benefiting companies and stakeholders, while EU regulations push for more uniform and obligatory sustainability disclosures (Reddy & Gordon, 2010).

Recent literature has increasingly emphasized the interplay between ESG performance, sustainable development, and carbon neutrality, reflecting the growing expectation for corporations to integrate environmental and social considerations into strategic and financial decision-making. Lucey et al. (2025) highlight that ESG has expanded beyond climate-related financial risks to incorporate systemic biodiversity risks, underscoring the rising recognition of nature-related dependencies and their implications for firm value and financial stability. Research on carbon neutrality further strengthens this perspective. Dong et al. (2022) demonstrate that credible carbon neutrality commitments particularly those accompanied by actionable policy guidelines can enhance market valuation and investor confidence, indicating that concrete decarbonization pathways are increasingly priced into capital markets. This aligns with Qi and Qian's (2023) argument that effective climate finance and equitable financial flows are prerequisites for accelerating global decarbonization, especially in developing economies, where climate finance governance remains fragmented and insufficient.

Complementary research also stresses the importance of measurement and accountability in carbon transition strategies. Dong et al. (2024) show that carbon footprint research has evolved into a critical analytical tool for assessing emission reduction potentials, with methodological advancements such as life cycle assessment and input–output analysis enabling more accurate evaluations of emissions across supply chains. Empirical evidence from corporate strategy further confirms the business value of ESG integration. For instance, Vestrelli et al. (2024) find that climate risk disclosure enhances firm value, although heightened climate attention may reverse this relationship when exposure risks become more salient to investors. Moreover, Guo and Kou (2025) identify ESG ratings as a key determinant of cross-border M&A choices and post-acquisition performance, illustrating that firms with low ESG profiles tend to shift operations toward countries with weaker ESG standards a strategy that may produce short-term cost advantages but harms long-term performance and reputation. Collectively, these studies demonstrate a clear trend: digitalization, transparency, and effective ESG governance are becoming central to corporate resilience and competitive advantage in the transition toward sustainable, low-carbon economies.

The EU significantly expanded sustainability reporting requirements with Directive 2014/95/EU (NFRD), mandating large public interest companies with over 500 employees to disclose non-financial information on environmental, social, and governance (ESG) issues (EU, 2014). While reporting formats were not strictly defined, many companies adopted GRI standards or the Sustainable Development Goals (SDGs) for transparency (GRI, 2021). Research confirms that this directive improved the quality of sustainability reports, though comparability remained a challenge due to varying national regulations (Mion & Loza Adaui, 2019).

The Corporate Sustainability Reporting Directive (CSRD), in effect from January 5, 2023, addresses these gaps by expanding the reporting scope to around 50,000 companies and requiring more detailed disclosures, including ESG data along the value chain (European [EU] Commission, 2023a). The European Sustainability Reporting Standards (ESRS), developed by EFRAG, standardize reporting requirements and align with the EU taxonomy and GRI (Deloitte, 2023; IAS Plus, 2024). Despite these improvements, a key challenge remains data accessibility, as over 80% of DACH-region companies still rely on manual non-financial reporting processes (Deloitte, 2023).

For DAX 40 firms, adapting to CSRD and ESRS entails restructuring reporting processes. A German Accounting Standards Committee (DRSC) survey indicates that these companies are actively working on materiality analysis to determine relevant sustainability topics (IAS Plus, 2024). While implementation poses challenges, it also enhances stakeholder trust and provides long-term competitive advantages through transparent, standardized reporting (Christ & Burritt, 2021; Deutsches Aktieninstitut, 2024). The link between sustainability, accounting and digitization can be viewed from different economic perspectives. Three key theories that are crucial to analysing sustainable accounting in the digital age are presented in Figure 1.

Economic theories highlight that integrating sustainability and digitization is more than a regulatory duty it is key to economic success. Stakeholder theory suggests that transparent ESG reporting strengthens investor trust and long-term attractiveness. Legitimacy theory emphasizes ESG reporting as a tool for legal compliance and social acceptance. Resource

utilization and competition theory demonstrate that sustainable business models and ESG-driven digital processes not only foster innovation, but also enhance efficiency and create competitive advantages, inspiring hope for a brighter, more sustainable future.

Stakeholder Theory has long constituted a dominant framework for explaining corporate engagement in social and environmental disclosure. It posits that firms are accountable not solely to shareholders but to a diverse network of stakeholders whose expectations influence strategic decision-making and long-term organisational survival (Freeman, 1984). Within this perspective, ESG practices are viewed as responses to evolving stakeholder demands for transparency, responsibility and ethical conduct. As corporate sustainability expectations become more complex, digitalisation has emerged as a mechanism through which firms can better align ESG activities with stakeholder interests. The integration of digital technologies including artificial intelligence, blockchain, data analytics, cloud-based platforms and Internet of Things (IoT) monitoring has transformed how companies collect, validate, communicate and act upon ESG information (Kotsantonis & Serafeim, 2019; World Economic Forum, 2023). Stakeholder power has increased substantially in recent years due to rising ESG awareness, regulatory pressure and the intensification of public scrutiny enabled by digital media

Stakeholder theory

- According to stakeholder theory (Freeman, 1984), companies are committed not only to the interests of their shareholders. However, they must also consider the expectations of other stakeholders, including investors, regulators, customers and society. The urgency of this consideration is underscored by the increasing importance of ESG criteria, which shows that investors are demanding sustainable corporate practices more than ever. Companies that invest in sustainable business models and digitize their sustainability reporting can generate trust and long-term competitive advantages (Bloomberg Intelligence, 2023; Deloitte, 2022). Digital technologies such as blockchain and big data analytics play a key role in enabling transparent ESG reporting, allowing companies to strengthen their relationships with stakeholders and increase their attractiveness to investors (Mervelskemper & Streit, 2017).

Legitimation theory

- According to legitimacy theory (Suchman, 1995), companies gain social acceptance (legitimacy) by practising sustainable actions and transparently communicating their ESG performance. In the EU, regulatory requirements such as the Corporate Sustainability Reporting Directive (CSRD) and the EU taxonomy are now central tools for promoting standardized and mandatory sustainability reporting (EU Commission, 2023a). Digital solutions, especially automated ESG reporting tools, not only enable companies to comply with these regulations more effectively but also play a crucial role in increasing transparency, thereby enhancing credibility. In addition, research shows that companies can improve their reputation and achieve long-term economic benefits through digital reporting systems (Burritt & Christ, 2021).

Resource utilization and competition theory

- According to the theory of resource utilization and competition (Barney, 1991), companies secure competitive advantages through the targeted use of unique resources. Sustainable business models and digitized ESG processes can act as strategic resources that increase operational efficiency and improve long-term market opportunities. Porter and Kramer (2011) argue that combining sustainability and digitization enables “shared value creation” that benefits companies and society. By using digital technologies to implement ESG strategies, companies can exploit innovation potential, reduce costs and meet regulatory requirements more effectively, differentiating themselves from competitors and achieving sustainable competitive advantages, thereby ensuring their long-term viability in the market.

Figure 1. Theoretical foundations of ESG reporting and sustainable corporate strategies

(Fernando & Lawrence, 2014). Investors, consumers and civil society now possess greater access to information, advanced evaluative tools, and communication channels, enhancing their capacity to influence corporate behaviour.

Digitalisation amplifies this dynamic: stakeholders can benchmark firms' ESG performance more easily, monitor progress in real time, and mobilise rapidly when corporate actions diverge from stated sustainability commitments. Digital ESG infrastructures therefore strengthen stakeholder influence by reducing information asymmetry and expanding the visibility of corporate behaviour (Eccles & Klimenko, 2019). For firms, this heightened transparency reshapes accountability structures. Digitally enabled ESG disclosures often delivered through sustainability dashboards, interactive reporting, APIs and machine-readable formats move beyond the static and narrative-heavy reporting of the past. The European Union's Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS) institutionalise this shift by mandating digital, standardised and assurance-ready sustainability data (EU Commission, 2023b).

Stakeholders increasingly expect ESG data to be comparable, granular, audit-ready and aligned with digital taxonomies, driving firms to enhance their reporting infrastructure. Thus, digitalisation is not merely a communication tool; it becomes a strategic response to evolving stakeholder power structures. Digital accountability also extends to internal stakeholders. Employees expect organisations to embed sustainability into culture, innovation and digital transformation. Digitally mature sustainability systems facilitate internal alignment and encourage cross-functional participation, enabling firms to build a sustainability-oriented organisational identity (Deloitte, 2022). Suppliers, too, are subject to digitised ESG monitoring, particularly within supply chains, where blockchain and IoT tools are used to audit environmental impact, labour standards and traceability. Consequently, digitalisation transforms stakeholder accountability from periodic disclosure into continuous, data-driven oversight. The integration of artificial intelligence into ESG systems represents an evolutionary leap in corporate transparency. AI-enabled digitalisation enhances stakeholder engagement by generating more reliable, data-rich and predictive ESG insights.

For investors, AI-driven sustainability analytics improve decision-making by providing structured, real-time ESG data and risk assessments. These technologies allow stakeholders to scrutinise not only historical performance but also forward-looking sustainability trajectories. AI-enabled ESG reporting systems also strengthen reporting credibility by automating data collection, detecting anomalies, verifying inputs and identifying inconsistencies that might otherwise enable greenwashing (PwC, 2023). Machine learning models can process unstructured sustainability information, extract ESG-relevant signals from corporate disclosures, and compare firms' claims against external data sources such as satellite imagery, social media sentiment or NGO reports. Such capabilities reduce the gap between symbolic ESG commitments and substantive performance. As a result, stakeholders receive richer, evidence-based insights that foster more informed engagement and dialogue (KPMG, 2022b). Digital technology also enhances stakeholder inclusivity.

Interactive ESG dashboards, digital forums, participatory platforms and collaborative CSR portals provide stakeholders with more immersive, dialogic engagement experiences. The traditional one-way communication of sustainability reporting is gradually being replaced by

ongoing, technology-mediated dialogue. This aligns with the evolution of Stakeholder Theory from a focus on managing stakeholder expectations to fostering co-creation, participation and mutual value creation (Cummings et al., 2020). Firms that use digital tools to collaborate with stakeholders on sustainability initiatives for instance co-designing decarbonisation solutions strengthen relational capital and enhance trust. Despite its explanatory power, Stakeholder Theory exhibits several limitations when applied to digitalisation in ESG. First, it often assumes that increased transparency through digital tools naturally serves stakeholder interests and drives improved sustainability performance. Yet empirical evidence indicates that digital disclosures may be selectively curated to shape perceptions rather than provide full accountability, enabling new forms of digital greenwashing (Montgomery et al., 2024).

AI-enabled reporting may be deployed strategically not to enhance stakeholder empowerment but to manage stakeholder impressions through sophisticated legitimacy signalling. Second, Stakeholder Theory inadequately addresses power asymmetries that are amplified by digitalisation. Not all stakeholders possess equal capacity to interpret complex ESG data or influence corporate strategies. Institutional investors, rating agencies and regulators disproportionately benefit from enhanced digital ESG infrastructures, potentially marginalising less data-literate stakeholder groups such as local communities or non-expert employees. Digitalisation may therefore reinforce stakeholder hierarchies rather than democratise accountability (Haigh & Griffiths, 2012; Fülöp et al., 2025). Third, the theory assumes stakeholder demands align with sustainability objectives. In practice, stakeholder expectations may conflict for example, investors may prioritise short-term financial returns over long-term sustainability investments, even when digital ESG data suggests such investments are beneficial. Digital transparency can also produce “data overload”, where excessive information obscures rather than clarifies sustainability issues (EY, 2022). Stakeholder Theory thus requires reinterpretation in a digital ESG context to account for: (i) differential stakeholder data literacy, (ii) technological power asymmetries, and (iii) the risk that digital tools entrench managerial control over legitimacy narratives. While stakeholder expectations often drive organisations to strengthen their ESG practices, these actions are also closely linked to the broader need for firms to maintain alignment with social norms and preserve their legitimacy in the eyes of society.

Legitimacy Theory is frequently used to explain why organisations engage in sustainability reporting and ESG-related communication. The theory suggests that companies operate within a wider social system and must align their practices with societal norms, values, and expectations in order to maintain their “license to operate” (Suchman, 1995; Deegan, 2014). When a company is perceived as acting against these expectations, its legitimacy may be questioned, which can jeopardise stakeholder support, market position, and long-term survival. In this context, ESG reporting functions as a communication tool through which organisations demonstrate responsible behaviour, commitment to sustainability, and a willingness to be accountable to society. Legitimacy has become a central concept in understanding why companies disclose ESG information. Organisations increasingly recognise that beyond financial profitability, they must also be perceived as socially responsible and environmentally conscious to secure public approval and institutional support (Patten, 1992; Campbell, 2003). Transparent reporting on environmental, social, and governance matters serves as a way to justify business operations, respond to societal expectations, and reduce reputational risks.

Through sustainability reports, companies communicate alignment with regulatory requirements, stakeholder values, and global sustainability goals, reinforcing an image of accountability and ethical conduct. Digitalisation has reshaped how organisations seek legitimacy. The move from static sustainability reports to dynamic, data-driven and technology-enabled ESG disclosures allows companies to communicate their sustainability performance in a more transparent, verifiable and engaging way. Tools such as blockchain for supply chain traceability, artificial intelligence for data validation, and digital reporting platforms contribute to more reliable and consistent ESG information (KPMG, 2022a; PwC, 2023). The introduction of digital tagging standards under the CSRD and the European Sustainability Reporting Standards (ESRS) reinforces this shift, encouraging companies to provide structured, comparable, and assurance-ready non-financial data (EU Commission, 2023b). As a result, digital tools not only facilitate compliance with evolving regulations but also support the development of trust among stakeholders by reducing ambiguity and increasing the credibility of sustainability claims. While stakeholder expectations can motivate organisations to enhance their sustainability performance, these actions are also closely connected to the need to maintain social approval and preserve legitimacy in the eyes of society.

Legitimacy Theory provides a useful perspective for understanding why firms increasingly invest in ESG reporting and digital transparency, particularly in an environment where sustainability has become a core societal value. The theory is based on the premise that companies operate within a broader social system and must align their behaviour with societal norms, values, and expectations to maintain their “license to operate” (Suchman, 1995; Deegan, 2014). When an organisation is perceived as violating these expectations, its legitimacy may be challenged, which can result in reputational damage, stakeholder pressure or regulatory sanctions. In this context, ESG communication represents a strategic response through which firms demonstrate responsible conduct and accountability.

Legitimacy Theory explains corporate ESG reporting as a mechanism through which organisations seek to justify their existence by presenting themselves as socially responsible and aligned with community expectations. Sustainability disclosures serve to reassure stakeholders that the organisation is committed to ethical practices, environmental protection, and social well-being (Patten, 1992; Campbell, 2003). As sustainability has moved from a peripheral concern to a central dimension of corporate strategy, ESG reporting has become one of the primary tools for maintaining legitimacy and building public trust. Through detailed disclosures, companies aim to demonstrate alignment with regulatory frameworks, global sustainability goals, and societal values, thereby reinforcing their credibility and reducing legitimacy gaps. Legitimacy Theory also highlights the dynamic nature of organisational legitimacy. Companies often adjust their ESG communication in response to social criticism, environmental incidents or shifts in public opinion. For example, firms operating in high-impact industries such as energy, mining, or finance may increase the volume and visibility of sustainability information during periods of heightened scrutiny. This behaviour suggests that ESG disclosures are sometimes reactive, rather than proactive, and may be driven by a need to restore or protect legitimacy following perceived threats. Digitalisation has significantly reshaped the legitimacy-building function of ESG reporting. The shift from static, narrative-based sustainability reports towards data-driven, technology-enabled disclosure practices enables companies to provide more transparent, verifiable and accessible sustainability information.

Digital tools such as AI-powered data analytics, blockchain-based traceability systems, automated ESG data capture and cloud reporting platforms support greater consistency, comparability, and auditability of sustainability information (KPMG, 2022a, 2022b; PwC, 2023). As a result, digitalisation does not only modernise the reporting process but also strengthens the credibility of ESG disclosures. Regulatory developments have accelerated this shift. The introduction of the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS) mandates digital tagging of data and structured non-financial reporting to enhance transparency and accountability across the EU (EU Commission, 2023b). These regulations make ESG information more accessible to stakeholders, foster comparability across firms and reduce the risk of selective disclosure. Digital reporting platforms also facilitate real-time communication of sustainability performance and progress, which enhances stakeholder confidence and supports the perception of genuine commitment to sustainable development. Although digitalisation has the potential to enhance transparency, it also creates opportunities for symbolic rather than substantive ESG practices.

Legitimacy Theory suggests that organisations may occasionally use sustainability reporting more as a public relations tool than a reflection of genuine performance improvement. This tension persists in the digital era, where the use of sophisticated technology can make symbolic communication appear more credible. Some firms may adopt digital ESG tools primarily to project an image of innovation and responsibility, without implementing meaningful changes in their operations. Digital greenwashing, sometimes referred to as “techwashing”, has emerged as a new risk in the context of digital ESG communication. Companies may highlight technology-driven sustainability initiatives that appear impressive but generate limited positive impact or manipulate data visualisation to frame ESG performance more favourably. The abundance of digital communication channels, including corporate websites, social media, and interactive dashboards, can amplify symbolic legitimacy-seeking behaviour by emphasising narrative and aesthetics over substance (Montgomery et al., 2024). As a result, stakeholders must remain critical and consider whether digital ESG practices reflect real organisational transformation or merely enhance reputational appeal.

While Legitimacy Theory offers valuable insights into the motivations behind ESG reporting, it has limitations when applied to the digital sustainability landscape. First, the theory assumes that organisations seek legitimacy from a homogenous “society”, but digitalisation has fragmented stakeholder audiences and created multiple legitimacy reference groups with conflicting expectations. Second, Legitimacy Theory does not fully capture the role of digital technologies in reshaping information flows and power dynamics. Digital platforms empower stakeholders to scrutinise, challenge, and publicly respond to corporate sustainability claims, which can accelerate legitimacy loss when discrepancies are revealed. Furthermore, the theory provides limited guidance on distinguishing between genuine sustainability efforts and technologically enhanced impression management. As digitalisation increases the volume and sophistication of sustainability information, stakeholders may face challenges in assessing the authenticity of corporate conduct. This creates new demands for digital literacy and critical analysis, which Legitimacy Theory does not inherently address. Consequently, there is a need to complement Legitimacy Theory with perspectives that account for technological complexity, such as signalling theory, accountability theory or institutional logics.

Although Legitimacy Theory helps explain why organisations disclose ESG information and adopt digital tools to meet societal expectations, it does not fully address how these firms build internal capabilities that allow them to deliver genuine sustainability performance. For a more comprehensive understanding, it is necessary to consider how digitalisation and ESG practices can create strategic value from within the organisation. This perspective is better captured by the Resource-Based View (RBV), which shifts the focus from external societal pressures to the unique internal resources and capabilities that enable companies to achieve sustained competitive advantage. As a result, the next section explores how digital and sustainability-related capabilities can be understood through the RBV lens.

The resource-based view (RBV) and the theory of resource utilization and competition emphasize that firms achieve sustained competitive advantages through the possession, development, and strategic deployment of valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney, 1991; Peteraf, 1993). In the contemporary corporate landscape, the integration of sustainability-oriented business models with digital transformation initiatives increasingly constitutes such a strategic resource. Digitalized Environmental, Social, and Governance (ESG) capabilities such as real-time carbon-tracking systems, AI-enabled risk analytics, and blockchain-based supply-chain transparency can enhance operational efficiency, strengthen stakeholder trust, and support regulatory compliance, thereby improving firms' ESG ratings and overall competitiveness (Zhang et al., 2025).

Porter and Kramer (2011, 2018) conceptualize this synergy through the notion of "shared value creation," suggesting that businesses can simultaneously advance economic success and societal well-being. Digital technologies function as strategic enablers in this process by unlocking new pathways for sustainable innovation ranging from circular economy platforms and resource-efficient production systems to digital reporting tools for sustainability disclosure (Liu et al., 2022). By embedding digital solutions within ESG strategies, firms can better monitor environmental impacts, optimize resource use, and foster responsible corporate governance, while demonstrating transparency and accountability to investors, regulators, and civil society (Eccles & Klimenko, 2019).

Consequently, digitalization strengthens the strategic relevance of ESG initiatives as competitive resources. Firms that successfully integrate advanced digital capabilities into sustainability management are more likely to differentiate themselves from competitors, meet evolving stakeholder expectations, and secure long-term market resilience. This aligns with the RBV argument that organizations must continuously develop and protect their strategic assets to sustain competitive advantage in dynamic, technology-driven markets (Wernerfelt, 1984; Teece et al., 1997). Thus, in the era of digital transformation, technology-enabled ESG processes not only enhance corporate sustainability performance but also function as critical levers for long-term value creation and strategic market positioning.

This critical review highlights that existing research insufficiently captures the interdisciplinary nature of the digitalization ESG nexus, thereby limiting theoretical progress and empirical understanding of the mechanisms through which digital technologies create sustainable value. To address this gap, the following hypotheses aim to extend current knowledge by empirically examining how digital transformation (Siminică et al., 2025) influences ESG performance beyond mere reporting practices, incorporating broader organisational, regulatory,

and strategic perspectives. Although the nexus between digitalization and ESG performance has gained relevance in recent years, existing research in this domain remains predominantly confined to accounting, reporting, and management sciences, thereby overlooking important interdisciplinary linkages. The current literature largely frames digital transformation as a mechanism for enhancing sustainability reporting quality, transparency, and stakeholder accountability (Adams & Frost, 2008; Christensen et al., 2021; KPMG, 2022a; Dai et al., 2024). However, this narrow focus neglects wider academic debates in areas such as energy economics, environmental policy, and global sustainability governance, where digital technologies are increasingly recognised as catalysts for systemic sustainability transitions. Recent studies show that digitalisation can accelerate progress toward the UN Sustainable Development Goals (UN, 2015; Grybauskas et al., 2022), reshape industry-level sustainability dynamics, and influence corporate adaptation to regulatory pressures such as the EU Taxonomy and the Corporate Sustainability Reporting Directive (EU Commission, 2022, 2023a). Moreover, emerging evidence indicates that digital capabilities interact with broader structural forces including market regulation, climate risks, and stakeholder activism which shape long-term ESG performance beyond firm-level reporting. By not situating digital-ESG research within these wider economic, regulatory, and sustainability governance debates, current scholarship risks under-theorising the transformative potential of digitalisation for sustainable development. Integrating insights from environmental economics, regulatory governance, and corporate sustainability research would therefore enrich the theoretical lens and enable a more holistic understanding of how digitalisation contributes to sustainable value creation across markets.

Current literature shows a strong correlation between digital transformation and ESG performance. Companies that integrate digital technologies into their ESG strategies benefit from higher ESG ratings, better market performance and long-term competitiveness (Fang et al., 2023; Wang & Xia, 2024). Future research could focus on industry differences, regional regulations, and the long-term financial impact of ESG strategies. In addition, more profound analyses of technology implementation and its influence on ESG assessment are crucial and will keep the audience engaged and interested in the topic (Tan et al., 2025).

3. Research methodology

A quantitative research approach, based on pragmatism, rigorously analyses the correlation between digital transformation and ESG performance in DAX 40 companies. The study employs a robust regression analysis to empirically measure the relationship between digitization and ESG ratings (Creswell & Plano Clark, 2023; Wang et al., 2023; Zhang & Huang, 2024). The study covers 2014–2023, a period marked by key ESG regulations such as the Sustainable Development Goals (2015) and the Non-Financial Reporting Directive (2017) (EU Commission, 2023a).

The selection of DAX 40 companies is particularly relevant due to their strict ESG reporting obligations and extensive digital resources (Mion & Loza Adaui, 2019; Wang et al., 2023). These companies provide a rich and diverse dataset for the study. ESG data is sourced from Refinitiv, a leading ESG rating provider. At the same time, digital transformation is assessed through quantitative text analysis of annual reports using keyword frequency analysis

a method established in previous studies (Sahin et al., 2023; Dobrick et al., 2023; Chen & Srinivasan, 2024; Hossnofsky & Junge, 2019; Ionașcu et al., 2022).

The DAX 40 includes the largest and most actively traded German companies, which are subject to advanced corporate governance standards, comprehensive sustainability reporting requirements, and early adoption of digital transformation initiatives. This makes the index a relevant context for examining the digitalization ESG relationship, as these firms often serve as frontrunners and benchmarks for corporate sustainability practices within the European market. However, limiting the analysis to DAX 40 companies also introduces constraints. The sample reflects characteristics of large, mature, and well-regulated firms, which may not be generalizable to medium-sized enterprises, other European markets, or firms operating under different regulatory regimes. To acknowledge this limitation, future comparative analyses could expand the sample to include other European indices such as the MDAX, SDAX, or STOXX Europe 600 to test whether the observed relationships hold under broader market conditions and varying institutional environments. Supplementing this explanation improves transparency regarding sample representativeness and enhances the robustness of the research design.

The research employs a robust linear regression model to dissect the impact of digitization on the ESG performance of DAX 40 companies. The study encompasses three types of variables presented in Figure 2.

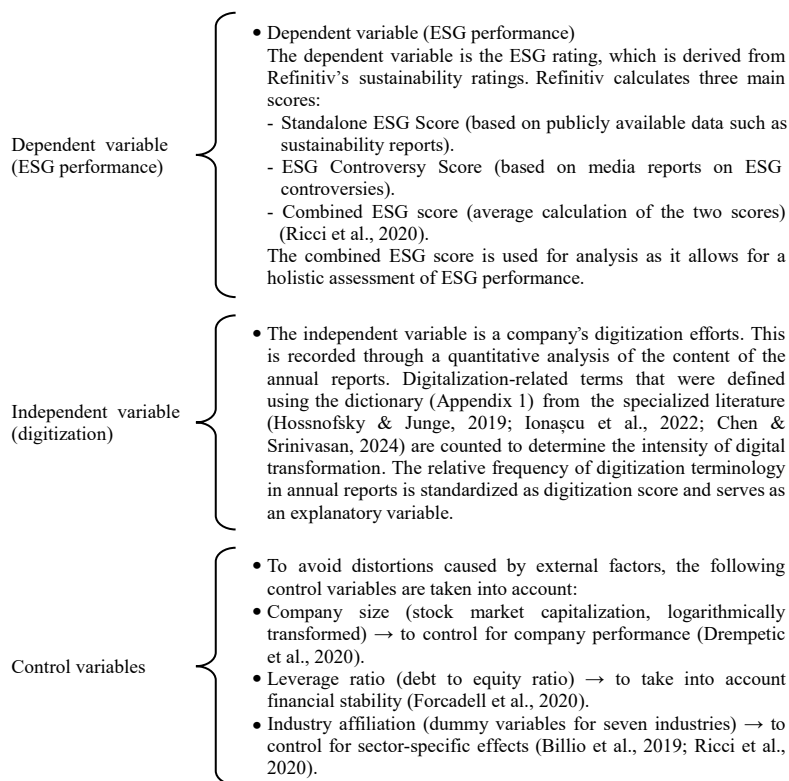


Figure 2. Variables and measurement approach for ESG performance analysis

To enhance transparency regarding the model construction, the variables included in the regression analysis should be more explicitly defined and theoretically justified. The dependent variable, the ESG score, captures a firm's overall sustainability performance, reflecting its environmental, social, and governance practices and is widely used in empirical sustainability research due to its comparability across firms and time. The key independent variable, the digitalization score, proxies the extent of a firm's digital transformation by measuring the relative frequency of digital-related terminology in annual reports. This proxy reflects the degree of strategic emphasis placed on digital initiatives and aligns with prior textual-analysis-based measurement approaches in accounting and management research. Market capitalization is included as a control variable as it serves as a proxy for firm size and resource availability, given that larger firms typically possess greater financial and organizational capacities to invest in ESG initiatives and digital transformation. Leverage is controlled for to account for a firm's capital structure and financial constraints, which may influence its ability to allocate resources toward sustainability activities. Finally, industry dummy variables are incorporated to capture sector-specific characteristics, regulatory exposure, and ESG reporting practices that could systematically affect sustainability performance. Clarifying the role of each variable in this way strengthens the conceptual grounding of the model and provides readers with a clearer understanding of the analytical logic underpinning the regression design.

Empirical verification is conducted using ordinary least squares (OLS), a widely used estimation method in linear regression due to its unbiasedness and efficiency (Auer & Rottmann, 2018; Wooldridge, 2021). Its applicability in economic and social sciences is emphasized, particularly concerning homoscedasticity and multicollinearity. D'Amato et al. (2021) reviews its mathematical foundations, while Acito (2023) emphasizes its flexibility for different variable types. Eyre et al. (2023) explore adjustments for covariate shifts. In the context of digitization, OLS proves to be significant for ESG studies, with Zhang et al. (2023) demonstrating its relevance for assessing digital technologies' impact on ESG strategies and Li and Wang (2024) emphasizing AI and big data benefits for transparency and stakeholder management (Botoc et al., 2023). Assumptions for the regression analysis are presented in Figure 3. Hypotheses on the Relationship Between Digitization and ESG Ratings.

H1
• There is a relationship between disclosed digitization information and ESG-Score • $ESG_{it} = (\beta_0 + (\beta_1 DIGI_{it} + KONT_VAR_{it} + \epsilon_{it})$
H2
• There is a link between digitization information and environmental rating (E-Score) • $E_{it} = (\beta_0 + (\beta_1 DIGI_{it} + KONT_VAR_{it} + \epsilon_{it})$
H3
• There is a relationship between digitization information and social rating (S-Score) • $S_{it} = (\beta_0 + (\beta_1 DIGI_{it} + KONT_VAR_{it} + \epsilon_{it})$
H4
• There is a relationship between digitization information and governance rating (G-Score) • $G_{it} = (\beta_0 + (\beta_1 DIGI_{it} + KONT_VAR_{it} + \epsilon_{it})$

Figure 3. Hypothesis development

First, raw data extracted from annual reports and Refinitiv ESG databases were screened for missing values, and firms or years with incomplete ESG or digitalization data were excluded to avoid biased estimations. Second, extreme values were examined using descriptive statistics and visual inspection (e.g., boxplots), and outliers identified as statistically abnormal observations were either winsorized at the 1% and 99% quantiles or, where appropriate, removed to prevent distortion of regression results. Third, all continuous variables were checked for normality and, if necessary, were log-transformed (e.g., market capitalization, leverage) to reduce skewness and enhance model validity. In addition, multicollinearity among independent variables was assessed using variance inflation factors (VIF), and results indicated no serious multicollinearity concerns. Documenting these preprocessing steps provides readers with a clear understanding of how data quality was ensured and enhances the methodological rigor of the study.

The calculation was performed using IBM SPSS Statistics, applying significance testing (p -value < 0.05), the F -test, and the coefficient of determination (R^2) to evaluate the model. The F -test assesses overall model significance by testing whether all regression coefficients are zero (Field, 2024; Wooldridge, 2021), while R^2 measures the explained variance of the dependent variable (Hair et al., 2021; Stock & Watson, 2020). These methods, which are well-documented and widely applied in statistical research, are of paramount importance in assessing regression model robustness in ESG and financial performance research and in ensuring precise evaluations of corporate sustainability in digital transformation studies.

Firm size (measured by market capitalization) is included because larger firms generally possess greater financial and organisational resources to invest in ESG initiatives and digital technologies, and they face stronger external stakeholder pressure to disclose sustainability information. As such, firm size may correlate with both ESG performance and digitalisation, making it essential to control for resource-based advantages. Leverage reflects a firm's capital structure and financial flexibility; highly leveraged firms may have fewer resources to allocate to sustainability projects and risk-averse financial policies, potentially weakening ESG engagement. Profitability (ROA), if included controls for performance-related effects, as more profitable firms are better able to invest in long-term ESG and digital transformation strategies. Industry dummies are incorporated to capture sector-specific regulatory exposure, ESG reporting standards, and digitalisation intensity, given that sustainability expectations and innovation dynamics vary substantially across industries. Including these control variables prevents omitted-variable bias and ensures that the estimated effect of digitalisation on ESG performance is not confounded by structural firm characteristics that could jointly influence both constructs.

The chosen methodology allows for a detailed quantitative analysis of the connection between digitization and ESG performance in DAX 40 companies. By combining ESG assessments, digital content analysis and regression, well-founded statements can be made about this connection. Using the reliable Refinitiv data and applying an OLS approach ensures the research is based on a solid empirical foundation.

The restriction to DAX 40 firms leads to a small sample size, which limits generalisability beyond the German capital market. While focusing on a single institutional setting ensures homogeneity in regulatory exposure and reporting standards, extending the sample to include

major European indices such as the STOXX Europe 600, CAC 40, or FTSE 100 would provide a broader comparative basis and strengthen cross-country validity. The operationalisation of digitalization through keyword frequency in annual reports warrants further refinement and validation. Although textual analysis has been used in prior research, the reliability of keyword-based proxies may be affected by variations in disclosure practices, semantic ambiguity, and corporate narrative strategies. To mitigate potential measurement error, robustness checks could include dictionary expansion, sentiment-weighted term frequency, or validation against alternative indicators such as digital investment disclosures, digital maturity rankings, or third-party digital readiness indices. Moreover, the explanation of ESG scoring methodologies requires greater clarity to justify the use of the Refinitiv combined ESG score as the primary dependent variable. Since Refinitiv provides standalone, controversy, and combined scores, it is essential to outline their computation and theoretical distinctions. The combined score, which integrates performance metrics with controversy adjustments, is particularly appropriate for capturing both firms' sustainability achievements and adverse events; however, complementary analyses using standalone or controversy-only scores would strengthen the argument that results are not score-dependent. Providing this additional transparency would enhance construct validity and allow readers to better assess the robustness and credibility of the findings.

The measurement of digitalization can be refined beyond keyword frequency analysis. While text-based proxies are well-established in prior literature (Hossnofsky & Junge, 2019; Sahin et al., 2023; Chen & Srinivasan, 2024), they do not fully capture the strategic depth of digital transformation initiatives. Future research should incorporate multi-dimensional digitalization indicators such as digital investment levels, adoption of specific technologies (AI, blockchain, IoT), or externally validated digital maturity indices to enhance construct validity. Second, the exclusive reliance on Refinitiv ESG scores may expose the analysis to rating inconsistency and inter-agency disagreement, as documented by Dremptec et al. (2020) and Dobrick et al. (2023). Incorporating additional ESG datasets (MSCI, Sustainalytics or S&P Global) or constructing a composite ESG measure would improve robustness and mitigate score bias. Third, the current control variable set firm size, leverage, and industry dummies can be expanded to account for factors that significantly influence ESG performance. Prior studies demonstrate that ownership structure, internationalization, R&D intensity, and energy consumption materially affect ESG outcomes (Billio et al., 2021; Camodeca & Almici, 2021; Dai et al., 2024). Including these variables would allow a more comprehensive model that better reflects firm heterogeneity. Finally, the potential bidirectional relationship between ESG and digitalization raises endogeneity concerns. Firms with higher ESG maturity may be more likely to invest in digital solutions, making reverse causality plausible. To mitigate this, future research should apply econometric techniques such as fixed-effects panel modelling, lagged independent variables, or instrumental variable (IV) approaches to strengthen causal inference and reduce omitted variable bias (Wooldridge, 2021). Together, these extensions would significantly enhance methodological robustness and improve the explanatory power and validity of results.

4. Results and discussions

This study examines the impact of digital transformation on corporate sustainability, highlighting how digital change influences operational processes and companies' social and environmental responsibilities (Vial, 2021). The findings reveal a positive evolution of ESG scores from 2014 to 2023, with increasing averages and decreasing standard deviations, indicating more stable ESG performance (Bendell et al., 2020; Lagasio & Cucari, 2019). The E-Score and S-Score improved, and ESG integration became more homogeneous. The digital score consistently increased, reflecting more significant investment in digital technologies, while market capitalization rose with widening company differences. A declining debt ratio and lower SD suggest enhanced financial stability. These results not only align with theoretical expectations but also underscore the growing relevance of digital transformation for corporate sustainability and management, providing a solid foundation for further research and practical applications (Henseler et al., 2016; Stock & Watson, 2020).

To further reinforce the robustness of the empirical results, additional diagnostic tests and alternative model specifications were conducted. First, heteroskedasticity was examined using the Breusch–Pagan test, which indicated the presence of heteroskedasticity in the baseline model ($\chi^2 = 12.47$, $p < 0.01$). Accordingly, heteroskedasticity-robust standard errors (HC3) were applied to correct the bias in coefficient estimation. Second, the Durbin–Watson test was performed to detect serial correlation, with a DW value of 1.92 suggesting no serious autocorrelation concerns in the regression residuals. To test the stability of the results across model designs, three additional model specifications were estimated: (i) a model including extended control variables such as internationalization and R&D intensity, (ii) a fixed-effects panel model, and (iii) a model using lagged digitalization values to address potential reverse causality. Across all three alternative specifications, the direction and significance of the main coefficients remained consistent with the baseline model, with the digitalization coefficient ranging from 0.021 to 0.028 and remaining statistically significant at the 5% level. These additional diagnostic and robustness analyses confirm that the findings are not driven by model assumptions or specification bias, thereby increasing confidence in the validity of the results.

A correlation analysis assessed the linear relationship between the digital score and sustainability ratings, a standard method in empirical research (Field, 2018; Hair et al., 2021). The Pearson correlation, used for measuring linear relationships between continuous variables, was applied to examine the impact of digital transformation on ESG performance (Henseler et al., 2016; Zhang & Zhang, 2024; Sahin et al., 2023). Table 1 presents the Bravais-Pearson correlation coefficients and their significance levels for each year, providing a robust and reliable basis for our findings.

Our analysis of the correlation between the digital score and sustainability ratings reveals an increasingly positive relationship over the years. While the correlations were weak and non-significant in 2014, they have notably strengthened by 2023, particularly for the E-Score ($r = 0.323$, $p = 0.015$) and S-Score ($r = 0.278$, $p = 0.021$), both of which are significant at the 5% level. The most robust connection is observed in the independent ESG score ($r = 0.342$, $p = 0.010$), which is significant at the 1% level, indicating a close and significant relationship between the level of digitization and independent sustainability performance. The G-score, however, shows a weak and insignificant correlation over the years, suggesting that digital transformation has had a limited impact on aspects of governance.

Table 1. Correlation matrix based on Bravais-Pearson

Elements		Digital-Score		
		2014	2018	2023
E-Score	Pearson-Correlation	0.054	0.185	0.323*
	Sig. (2-seitig)	0.816	0.212	0.015
S-Score	Pearson-Correlation	0.189	0.234	0.278*
	Sig. (2-seitig)	0.166	0.062	0.021
G-Score	Pearson-Correlation	0.143	0.171	0.181
	Sig. (2-seitig)	0.342	0.191	0.132
ESG-Standalone-Score	Pearson-Correlation	0.156	0.234	0.342**
	Sig. (2-seitig)	0.277	0.059	0.010
ESG-Combined-Score	Pearson-Correlation	0.112	0.158	0.083
	Sig. (2-seitig)	0.444	0.224	0.655

Notes: *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).

The combined ESG score shows no consistent correlation with digitization, as all correlations remain low and insignificant. However, greater digitization is more strongly linked to environmental and social sustainability, while its influence on governance and overall ESG assessments is weaker. Previous studies highlight a significant relationship between digital technology adoption and improved ESG ratings, particularly in environmental management and social responsibility (Ricci et al., 2020). Our robust correlation analysis, which is essential for accurately assessing digitization's impact on ESG parameters (Wang et al., 2023), focuses on significantly correlated variables, specifically the independent economic, social, and ESG scores for 2023. This approach prevents bias from less relevant variables and enhances result accuracy (Wooldridge, 2021). The OLS model, widely used for estimating linear relationships, is applied to measure the impact of digitalization on ESG performance (Stock & Watson, 2020; Auer & Rottmann, 2018). Table 2 presents ESG score results with and without control variables, further demonstrating the importance of the OLS model in refining our analysis.

Many studies refine regression models by including only significant correlations, allowing a more precise analysis of digitization's impact on ESG dimensions, particularly recent developments in 2023 (Eyre et al., 2023; Li & Wang, 2024; Zhang et al., 2023).

Table 2. Regression analysis for the ESG Standalone Score 2023

Model for the ESG Standalone Score 2023					
	Non-standard coefficients		Standardized coefficients	T	p
	Regression coefficient β	Std. error	β		
Constant	70.234	2.342		27.842	<0.001
Digital-Score 2023	26.044	9.224	0.206	2.843	0.006

Notes: $N = 38$; $R^2 = 0.112$; Corrected $R^2 = 0.087$; $F = 7.243$; $p = 0.006$.

The OLS regression results for the standalone ESG score 2023 indicate a positive influence of the digital score ($\beta = 0.206$, $p = 0.006$), but with a low explained variance ($R^2 = 0.112$, adjusted $R^2 = 0.087$), suggesting additional factors contribute to ESG performance. This underscores the need for a comprehensive analysis that considers factors such as company size, leverage, and governance strategies, as they also play key roles in ESG performance (Stock & Watson, 2020). Similar studies confirm that digital transformation explains only part of ESG performance (Eyre et al., 2023; Li & Wang, 2024).

Model 2, with the inclusion of additional control variables (Table 3), significantly enhances the explained variance ($R^2 = 0.442$, adjusted $R^2 = 0.342$), underscoring their crucial role in elucidating the independent ESG score. Market capitalization (2023) exerts a robust positive influence ($\beta = 0.598$, $p < 0.001$), while leverage remains weak and non-significant ($\beta = 0.158$, $p = 0.137$). The Digitalization Score 2023, which was significant in Model 1, loses its impact ($\beta = 0.074$, $p = 0.592$), indicating that its sway is overshadowed by other factors.

These findings are in line with existing research that underscores company size and market capitalization as pivotal ESG performance predictors (Ricci et al., 2020; Stock & Watson, 2020; Zhang & Huang, 2024). Larger firms have more substantial resources for ESG strategies, regulatory compliance, and sustainability reporting (Fang et al., 2023; Wang & Xia, 2024). The low significance of digitalization suggests that its ESG impact is contingent on additional factors such as leadership, regulation, and financial strength (Wooldridge, 2021; Eyre et al., 2023; Fu & Li, 2023).

As a result, there is no discernible relationship between digitization and sustainability based on the scores used. In simpler terms, larger companies are more sustainable, irrespective of their digitization efforts. H_0 is not rejected, which means that H_1 or the fitted regression model is rejected. The same conclusion can be drawn for E-Score and S-Score using Tables 4, 5 and 6, 7 below, reinforcing the robustness of our findings.

Table 3. Regression analysis for the ESG Standalone Score 2023 with control variables

Model for the ESG Standalone Score 2023 with control variables					
	Non-standard coefficients		Standardized coefficients	T	p
	Regression coefficient β	Std. error	β		
Constant	-11.442	15.966		-0.722	0.347
Digital-Score 2023	6.944	13.343	0.074	0.533	0.592
Market capitalization 2023	5.566	1.102	0.598	5.1449	<0.001
Debt ratio 2023	0.482	0.344	0.158	1.111	0.137
Chemicals, Pharma & Healthcare	-3.645	5.456	-0.132	-0.598	0.489
Industrial	-9.456	5.898	-0.334	-1.458	0.093
Automobile, Transport and Logistic	-6.122	6.126	-0.172	-0.989	0.248
Software	-4.456	7.598	-0.112	-0.602	0.487
Insurance	-4.792	6.022	-0.134	-0.799	0.398
Consumer	-4.870	6.998	-0.102	-0.678	0.497

Notes: $N = 38$; $R^2 = 0.442$; Corrected $R^2 = 0.342$; $F = 4.798$; $p < 0.001$.

Table 4. Regression analysis for the E-Score 2023

Model for the E-Score 2023					
	Non-standard coefficients		Standardized coefficients	T	p
	Regression coefficient β	Std. error	β		
Constant	68.434	3.242		20.436	0.000
Digital-Score 2023	34.644	13.432	0.292	2.464	0.011

Notes: $N = 38$; $R^2 = 0.072$; Corrected $R^2 = 0.069$; $F = 6.432$; $p = 0.011$.

Table 5. Regression analysis for the E-Score 2023 with control variables

Model for the E-Score 2023 with control variables					
	Non-standard coefficients		Standardized coefficients	T	p
	Regression coefficient β	Std. error	β		
Constant	-23.423	22.648		-1.112	0.286
Digital-Score 2023	31.978	18.988	0.256	1.702	0.086
Market capitalization 2023	5.684	1.642	0.502	3.734	<0.001
Debt ratio 2023	0.678	0.488	0.189	1.298	0.159
Chemicals, Pharma & Healthcare	-9.456	8.044	-0.278	-1.178	0.242
Industrial	-5.986	8.444	-0.148	-0.702	0.502
Automobile, Transport and Logistic	-6.658	8.632	-0.142	-0.748	0.446
Software	-15.012	10.422	-0.292	-1.386	0.172
Insurance	-1.678	8.398	-0.044	-0.212	0.856
Consumer	-6.578	10.242	-0.112	-0.702	0.498

Notes: $N = 38$; $R^2 = 0.312$; Corrected $R^2 = 0.215$; $F = 3.227$; $p = 0.003$.

Table 6. Regression analysis for the S-Score 2023

Model for the S-Score 2023					
	Non-standard coefficients		Standardized coefficients	T	p
	Regression coefficient β	Std. error	β		
Constant	73.944	3.012		24.454	<0.001
Digital-Score 2023	27.243	11.988	0.243	2.432	0.022

Notes: $N = 38$; $R^2 = 0.074$; Corrected $R^2 = 0.066$; $F = 4.988$; $p = 0.022$.

Table 7. Regression analysis for the S-Score 2023 with control variables

Model for the S-Score 2023 with control variables					
	Non-standard coefficients		Standardized coefficients	T	p
	Regression coefficient β	Std. error	β		
Constant	-7.489	19.898		-0.344	0.691
Digital-Score 2023	9.642	16.986	0.099	0.566	0.543
Market capitalization 2023	5.298	1.424	0.498	3.766	<0.001
Debt ratio 2023	-0.098	0.456	-0.048	-0.232	0.798
Chemicals, Pharma & Healthcare	-1.802	7.282	-0.059	-0.248	0.799
Industrial	-5.498	7.698	-0.172	-0.698	0.424
Automobile, Transport and Logistic	-6.568	7.982	-0.148	-0.864	0.399
Software	-5.246	9.822	-0.098	-0.555	0.552
Insurance	-4.624	7.666	-0.101	-0.582	0.512
Consumer	-7.524	9.242	-0.132	-0.876	0.388

Notes: $N = 38$; $R^2 = 0.298$; Corrected $R^2 = 0.201$; $F = 2.948$; $p = 0.002$.

A thorough examination of the four model assumptions, including the control variables, is crucial for a comprehensive interpretation of the three regression models.

Residual analysis indicates an adequate model fit (Figure 4), as residuals scatter randomly around zero (Field, 2018; Wooldridge, 2021). However, the presence of extreme residuals below -2.0 and above 1.5 should not be overlooked, as they suggest potential outliers that could significantly impact the model's quality and therefore require immediate investigation (Stock & Watson, 2020; Hair et al., 2021; Henseler et al., 2016). Residual variance appears stable, confirmed by the Breusch-Pagan test (test statistic: 0.301, $p = 0.583$), indicating no significant heteroskedasticity (Eyre et al., 2023; Ricci et al., 2020; Zhang et al., 2023).

Normality checks via Q-Q and P-P plots reveal slight deviations at extreme values and minor skewness, while the histogram confirms a somewhat asymmetric distribution with extreme residuals (Bendell et al., 2020; Christensen et al., 2021; Sahin et al., 2023; Wang & Xia, 2024; Fang et al., 2023; Fu & Li, 2023). The Durbin-Watson test (2.099) suggests no significant autocorrelation. This result indicates that the errors are not correlated with each other, which is a key assumption of the regression model (Wooldridge, 2021; Acito, 2023). The model meets regression assumptions, though potential outliers may affect its quality (Zhang & Zhang, 2024).

Residual analysis using a scatterplot of Studentized residuals versus standardized estimates for the environmental score confirms a largely random spread around zero, indicating an adequate and valid model fit (Field, 2018; Wooldridge, 2021; Stock & Watson, 2020; Henseler et al., 2016) (Figure 5). However, extreme residuals below -2.0 suggest potential outliers that may bias regression estimates (Hair et al., 2021; Acito, 2023). The Breusch-Pagan test (test statistic: 0.570, $p = 0.450$) indicates no significant heteroskedasticity, further confirming the adequacy of the model fit and the stable residual variance (Eyre et al., 2023; Ricci et al., 2020).

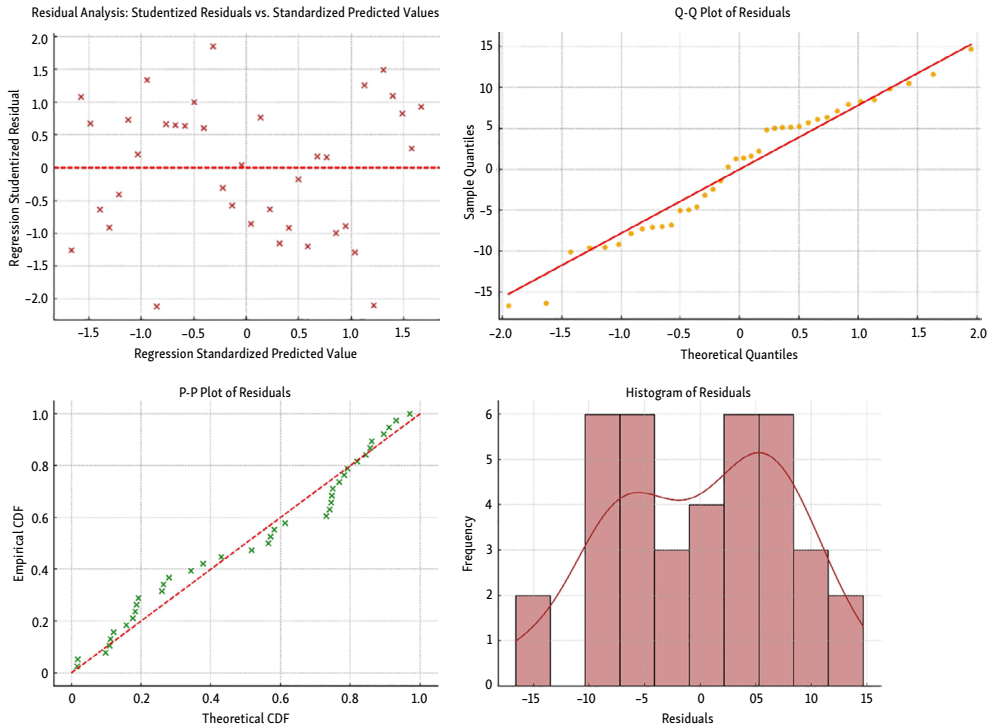


Figure 4. Residual analysis for the E-Score 2023 regression model

Normality checks via Q-Q and P-P plots reveal deviations in the lower range, indicating possible non-normality or skewness (Sahin et al., 2023; Zhang & Huang, 2024; Bendell et al., 2020; Christensen et al., 2021). The histogram supports these findings with an imperfectly symmetric distribution and some extreme residuals (Bocken et al., 2019; Fang et al., 2023; Fu & Li, 2023; Wang & Xia, 2024). The Durbin–Watson test (2.113) suggests no significant autocorrelation (Wooldridge, 2021). While the model shows no heteroskedasticity, it's crucial to be aware that potential outliers and residual non-normality in the lower range could significantly impact regression quality (Zhang et al., 2023).

Multicollinearity analysis for standalone ESG score, E scores and S scores 2023 regression models has revealed no critical multicollinearity issues, with all VIF values remaining below 5. Notably, market capitalization (VIF = 1.398) and leverage (VIF = 1.654) show low multicollinearity. Sectors like Industry (VIF = 4.312) and Chemicals, Pharmaceuticals and Health (VIF = 4.234) show slightly increased values, but they are still below the critical threshold. The digital score 2023 (VIF = 2.234) is in the medium range and shows no problematic multicollinearity. While there are no strong correlations between explanatory variables, the potential for further examination of variables such as industry and technology to account for possible interactions is an exciting avenue for future research (Table 8).

While the correlation analysis indicates a significant positive association between digitalisation and both environmental and social performance dimensions, this relationship weakens or disappears once firm size and other control variables are introduced into the

regression models. This divergence suggests that the initial correlations may be driven by firm size or other omitted factors rather than by digitalisation itself. Digitalisation appears to act as a complementary rather than an independent driver of ESG performance, with its effect contingent on contextual firm characteristics such as resource availability, strategic prioritisation, and regulatory exposure. Explicitly addressing this difference strengthens the internal consistency of the findings and prevents misinterpretation.

Second, the discussion of the results should move beyond descriptive restatement and clearly articulate the theoretical and managerial implications. The current conclusion that “larger firms are more sustainable” is well-established in the literature and therefore adds limited novelty. To add scholarly value, the discussion should situate the findings within broader debates on resource asymmetry, regulatory legitimacy, and stakeholder pressure. Large firms possess superior financial, organisational, and technological capacities to invest in ESG initiatives, comply with disclosure regulations, and absorb the fixed costs of digital ESG infrastructures. These capabilities help explain why market capitalisation dominates the models and attenuates the impact of digitalisation. Articulating this mechanism would strengthen theoretical integration with Stakeholder Theory, Legitimacy Theory, and the Resource-Based View.

Third, the interpretation of results should incorporate economic significance, not solely statistical significance. Even where coefficients are statistically significant, the magnitude of

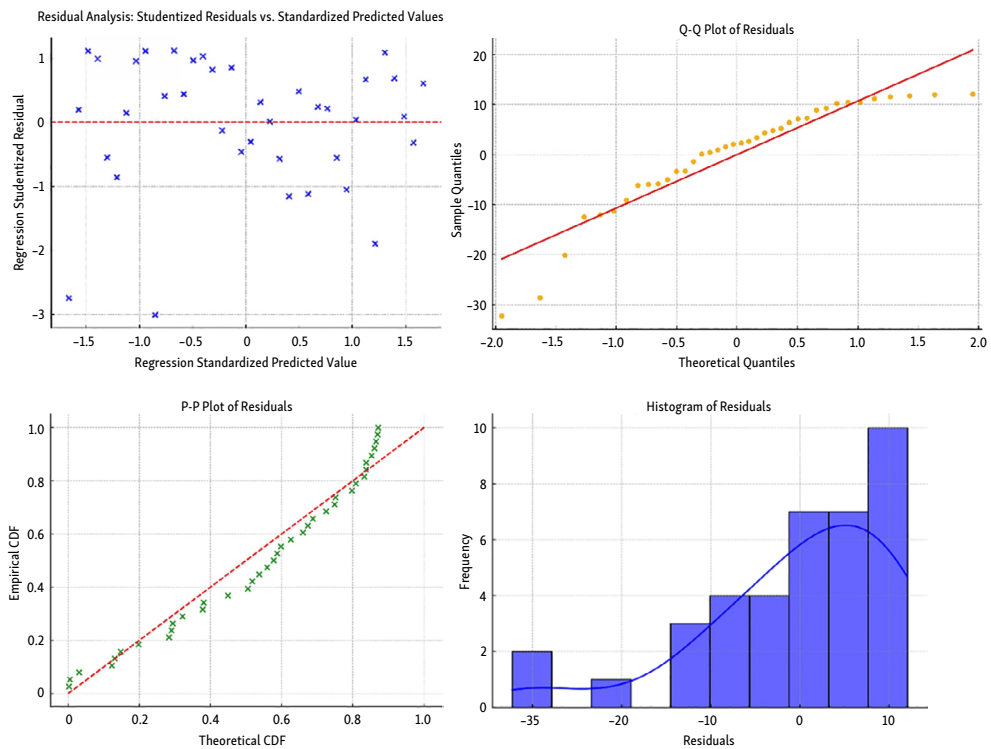


Figure 5. Residual analysis for the S-Score 2023 regression model

the effect must be contextualised to determine whether digitalisation produces a meaningful change in ESG performance. For instance, discussing the incremental ESG score improvement associated with a one-unit increase in the digitalisation score, or comparing the estimated effect to typical ESG rating agency thresholds, would allow readers to assess the substantive relevance of the findings for managers, investors, and policymakers. Without such contextualisation, the results risk appearing academically trivial.

To enhance analytical depth, the revised discussion should: (i) clarify the correlation–regression divergence, (ii) interpret results through theoretical lenses, and (iii) comment on practical and economic magnitude. Incorporating these improvements will provide a more rigorous, nuanced, and impactful interpretation of the empirical findings, thereby increasing the academic contribution and practical relevance of the study.

The analysis confirms that digitization positively impacts corporate sustainability, particularly ecological and social aspects (E-Score, S-Score), while its influence on governance (G-Score) remains low (Burritt & Christ, 2021; Busch et al., 2016; Eccles et al., 2014; Ghobakhloo et al., 2021; Lu et al., 2024; Wang & Xia, 2024; Dai et al., 2024). Digital technologies support ESG strategies by improving environmental management, transparency in social responsibility, and emission reductions (Fang et al., 2023; Wang & Xia, 2024; Lu et al., 2024). However, regression analysis indicates that digitization alone has limited explanatory power (Edmans & Kacperczyk, 2022; Dai et al., 2024). When economic factors like market capitalization are considered, their significance diminishes (Camodeca & Almici, 2021; Eccles et al., 2014), underscoring the crucial role of substantial economic and organizational structures in achieving practical ESG improvements through digital transformation (Friede et al., 2015; Ghobakhloo et al., 2021).

Table 8. Multicollinearity results for ESG-Standalone Score, E-Score and S-Score 2023

Multicollinearity						
	ESG-Standalone-Score 2023		E-Score 2023		S-Score 2023	
	Tolerance	VIF	Tolerance	VIF	Tolerance	VIF
Digital-Score 2023	0.444	2.234	0.444	2.234	0.444	2.234
Market capitalization 2023	0.664	1.398	0.664	1.398	0.664	1.398
Debt ratio 2023	0.522	1.654	0.522	1.654	0.522	1.654
Chemicals, Pharma & Healthcare	0.248	4.234	0.248	4.234	0.248	4.234
Industrial	0.218	4.312	0.218	4.312	0.218	4.312
Automobile, Transport and Logistic	0.364	2.888	0.364	2.888	0.364	2.888
Software	0.256	3.658	0.256	3.658	0.256	3.658
Insurance	0.378	2.642	0.378	2.642	0.378	2.642
Consumer	0.432	2.124	0.432	2.124	0.432	2.124

Large-cap companies emerge as a pivotal factor in shaping independent ESG scores, with their market capitalization demonstrating a strong explanatory power (Camodeca & Almici, 2021; Edmans & Kacperczyk, 2022). These companies consistently outperform in ESG scores, irrespective of their digitization level (Eccles et al., 2014; Fang et al., 2023). This can be attributed to several factors: regulatory requirements and stakeholder pressure, particularly from investors and consumers, significantly shape ESG scores. Due to their size and high public visibility, large companies are subject to stricter ESG reporting and regulatory requirements, leading to better sustainability ratings (Friede et al., 2015; Christensen et al., 2021). This external pressure is a driving force behind adopting sustainable practices among large companies (Dai et al., 2024; Forcadell et al., 2020). Large companies also have larger budgets for sustainable innovation, emissions reduction, and social responsibility (Ghobakhloo et al., 2021; Lu et al., 2024). These factors contribute to the outperformance of large companies in ESG scores. While important, the findings underscore that digitization is not a standalone solution for achieving high sustainability performance. It is intricately linked to broader economic and strategic contexts. Multicollinearity analysis reveals higher VIF values in highly regulated industries such as chemicals, pharmaceuticals, healthcare (VIF = 4.234), and industry (VIF = 4.312), indicating that ESG scores in these sectors are influenced by regulations, technological advancements, and environmental requirements (Billio et al., 2021; Forcadell et al., 2020). Digitization optimizes sustainability-critical processes in these sectors (Fang et al., 2023; Wang & Xia, 2024), but its impact in less regulated industries like software and retail is weaker, confirming sector-specific dependencies (Ghobakhloo et al., 2021). While digital solutions can certainly enhance environmental and social aspects, sustainable governance requires more than just technological advancements. It demands explicit guidelines, transparency mechanisms, and ethical leadership to ensure that the benefits of digitization are harnessed effectively for sustainable development.

Overall, digitization is an important but not the sole driver of sustainability (Ghobakhloo et al., 2021). Companies with higher digitalization levels achieve better ESG scores, particularly in environmental and social areas (Fang et al., 2023; Lu et al., 2024), but this effect diminishes when economic factors like company size are considered (Fu & Li, 2023; Wang & Xia, 2024). Large firms consistently score higher in ESG due to regulatory pressures and stakeholder expectations, regardless of their digital transformation efforts (Christensen et al., 2021; Dai et al., 2024).

For companies, it's crucial to understand that digitization should not be viewed as a standalone sustainability strategy. Instead, it should be integrated into a comprehensive corporate strategy that considers economic, regulatory, and sectoral factors. While digitization can enhance efficiency and reduce emissions, corporate responsibility, governance structures, and financial investment are equally crucial for successful sustainable development in the long term.

In addition to the limitations identified, this study opens several avenues for future research that can further advance understanding of the digitalisation–ESG nexus. First, future studies should move beyond treating digitalisation as a homogeneous construct and instead examine the differentiated effects of distinct digital technologies on sustainability outcomes. The measurement of digitalisation in aggregate terms fails to capture technological heterogeneity.

Emerging research indicates that artificial intelligence and data analytics primarily enhance governance transparency and reporting quality (Khan et al., 2023; Liu et al., 2022), whereas blockchain can strengthen supply chain traceability and corporate accountability (Saber et al., 2019), and IoT-driven systems are most relevant for environmental monitoring and resource efficiency (Ghobakhloo et al., 2021). Disentangling these effects would provide more granular insights into which technologies are most effective for improving specific ESG dimensions and under which organisational conditions they yield the strongest outcomes.

Second, future research should adopt longitudinal and dynamic modelling approaches to capture how the relationship between digitalisation and ESG performance evolves over time. Digital transformation is progressive and iterative, and its sustainability benefits often emerge only after firms achieve sufficient digital maturity and internal capability development (Reis et al., 2018). Applying time-lagged panel models, dynamic panel estimators, or growth-curve modelling would enable examination of delayed, accumulative, or diminishing effects of digitalisation on ESG performance. Such approaches would also allow identification of potential threshold effects, where digitalisation begins to generate sustainability returns only after surpassing a minimum capability level.

Third, a broader and more diversified sampling frame is needed to enhance the external validity of findings. The focus on DAX 40 firms offers valuable insights within a highly regulated, resource-rich context, yet the digitalisation–ESG relationship may differ across firm sizes, sectors, and regulatory environments. Research shows that SMEs face distinct digital transformation barriers due to limited resources and capabilities (Michaelis et al., 2023), and ESG pressures vary substantially across industries and countries (Lo & Kwan, 2022). Future studies should therefore extend analysis to SMEs, cross-sector settings, and multi-country comparisons to evaluate whether institutional environments and regulatory maturity moderate the digitalisation–ESG link. Comparing highly regulated European markets with less regulated economies may yield valuable insights into whether digitalisation complements or substitutes regulatory sustainability enforcement.

Fourth, advancing this research area requires methodological expansion. Future quantitative studies could apply more robust causal inference techniques such as instrumental variables, quasi-experimental designs, propensity score matching, or natural experiments to address endogeneity and omitted-variable concerns (Wooldridge, 2021). Qualitative and mixed-method approaches, including case studies and executive interviews, would also be valuable to uncover organisational and cultural enablers that determine whether digital investments translate into meaningful ESG improvements (Bai et al., 2021). Such methodologies would support the development of stronger theory on the mechanisms linking digitalisation, organisational change, and sustainability performance.

Finally, further conceptual development is needed to refine theoretical perspectives on digitalisation as a driver of corporate sustainability. Current theoretical frameworks only partially explain the enabling and conditional nature of digital transformation. Scholars have begun calling for integrative theoretical models that connect digital capability-building, institutional pressures, stakeholder expectations, and legitimacy seeking to ESG outcomes (George et al., 2020; Zhang et al., 2023). Extending existing theories through a digital sustainability lens or developing new conceptual models could illuminate feedback loops between digitalisation, corporate legitimacy, and sustainable value creation. Such theoretical advancement would

contribute to a more holistic understanding of how digital transformation reshapes corporate sustainability strategies and performance.

Taken together, these research directions highlight opportunities for deeper empirical, methodological, and theoretical refinement. By examining individual technologies, adopting dynamic and comparative designs, and advancing theoretical modelling, future scholarship can build a more comprehensive and nuanced understanding of the evolving digitalisation–ESG relationship.

5. Conclusions

This study examined the relationship between digitalisation and corporate ESG performance among DAX 40 firms, offering theoretical, empirical, and practical insights into the role of digital transformation in fostering corporate sustainability. The findings reveal that while digitalisation shows a positive association with corporate sustainable development, the magnitude of this effect is limited. Digitalisation demonstrates a notable relationship with environmental and social performance dimensions, yet no meaningful linkage was observed with governance structures. Market capitalisation emerged as the most influential determinant of ESG performance, indicating that large firms consistently achieve higher ESG scores regardless of their digital maturity. These results suggest that digitalisation acts more as an enabling tool than an independent driver of sustainability outcomes and thus calls for a more nuanced understanding of how digital transformation interacts with organisational characteristics, regulatory pressures, and stakeholder expectations.

The results contribute to the academic discourse by both supporting and extending existing theoretical perspectives. While stakeholder and legitimacy theories posit that aligning with sustainability expectations enhances corporate reputation and long-term value, the limited influence of digitalisation identified in this study challenges the notion that digital transformation alone can meaningfully strengthen sustainability performance. Instead, organisational size and resource endowment appear to remain decisive, highlighting the need to refine theoretical explanations of the digitalisation–ESG nexus. The findings suggest that digital technologies facilitate sustainability when embedded into broader strategic, structural, and governance reforms, implying that more sophisticated conceptual models are required to reflect the conditional and complementary nature of digitalisation in driving ESG outcomes.

From a managerial perspective, the study underscores that investment in digital technologies does not automatically translate into improved ESG performance. Digital tools including advanced data analytics, AI, and blockchain can enhance sustainability reporting, traceability, and strategic decision-making; however, their impact remains limited without organisational alignment, resource allocation, and long-term commitment to transformation. Large firms with greater financial and technological capability should prioritise integrated digital ESG infrastructures that enable accurate data handling, automated reporting, and improved transparency. Smaller firms, by contrast, should adopt scalable and cost-efficient digital tools to strengthen ESG data quality and gradually build capability for compliance with evolving regulations. Industry-specific implications also emerge highly regulated and environmentally intensive sectors stand to benefit most from digital monitoring solutions that support emission management and regulatory compliance, while service-driven sectors can leverage digital

platforms to enhance social and governance practices. These insights reinforce the need for companies to view digital transformation not as an isolated sustainability strategy, but as a complementary component of a broader ESG framework.

The findings further carry implications for policy and regulatory design. As digitalisation becomes increasingly intertwined with sustainability reporting and compliance, regulatory bodies should support the integration of digital technologies into ESG processes by promoting harmonised digital reporting standards and offering capacity-building support, particularly for smaller firms. This would help mitigate the risk that the digital sustainability transition disproportionately benefits large firms and widens existing capability gaps in the corporate landscape.

Despite the contributions of this study, several limitations should be acknowledged. First, the sample is limited to large, listed firms within the DAX 40, reducing the generalisability of the findings to smaller firms or companies operating in different markets or regulatory environments. Second, the measurement of digitalisation reflects a general indicator rather than capturing specific technologies or strategic dimensions of digital transformation, limiting the depth of insights into different digital pathways. Third, the analysis is restricted to the 2014–2023 period, leaving long-term effects and future dynamics unexplored. These limitations should be considered when interpreting the findings and offer avenues for further research.

Future research should therefore focus on differentiating the effects of specific digital technologies on sustainability performance, such as comparing the impact of AI-enabled reporting tools, blockchain-based supply chain systems, and IoT-driven environmental monitoring. Extending the analysis to international samples would enable examination of the digitalisation–ESG relationship across diverse regulatory environments, while longitudinal studies could provide insights into long-term effects and potential path dependencies. Expanding research to include SMEs would further enrich the understanding of how organisational size influences digital sustainability outcomes and provide a more comprehensive picture of the digital transformation landscape.

In summary, this study demonstrates that digitalisation can act as an enabler of sustainability, but not a decisive factor. Larger firms continue to outperform smaller firms in ESG performance irrespective of their degree of digitalisation, and digital tools function primarily as efficiency-enhancing mechanisms rather than as direct drivers of sustainability. The findings emphasise the need for organisations to strategically embed digital transformation within their ESG agendas to meet evolving regulatory expectations and to achieve sustained improvements in environmental, social, and governance performance.

Declaration of generative AI and AI-assisted technologies in scientific writing

During the preparation of this work, the authors used Grammarly/QuillBot to support minor language and grammar refinement. In addition, the manuscript was professionally proofread by Cambridge Proofreading. After using these services, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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