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Green Digital Transformation Enhances Environmental Social and Governance Performance in the Energy Sector

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Abstract

The strategic implementation of digital technologies is a crucial factor for lowering costs and enhancing operational efficiency in organizations, optimizing production processes and promoting sustainable development. In this context, comprehending the precise influence of digital transformation on firms' environmental, social, and governance (ESG) outcomes is crucial for advancing sustainable development in China's economy and society. This research examined energy firms in four nations (Iraq, Bahrain, the UAE, and Saudi Arabia) and specifically investigated how digital transformation influences ESG performance enhancement. The findings indicated that digital transformation greatly enhances ESG performance, especially in non-state-owned enterprises (SOEs) in contrast to SOEs. In particular, digital transformation efforts enhance ESG performance by boosting the number of highly skilled employees and enhancing the skills of the current workforce. Additionally, environmental regulations diminish the beneficial effects of digital transformation on both the number and proficiency of a company's workforce, subsequently influencing their ESG performance at the organizational level. A questionnaire was designed for data collection based on previous studies. A random sample of employees in energy companies in four countries (Iraq, UAE, Bahrain, and Saudi Arabia) was selected. The questionnaire was distributed using Google Forms, and the sample size was (774) valid questionnaires. The data were analyzed using SPSS and Amos software. The results showed a strong relationship between green digital transformation and environmental, social, and governance (ESG) performance.

1. Introduction

Businesses are progressively understanding the significance of incorporating sustainable development into their strategic frameworks as a crucial factor for economic and social advancement. Sustainable development within companies acts as an essential measure of their holistic sustainability, incorporating economic, environmental, and social aspects[1]. The ecological, The ESG ethos emphasizes the thorough evaluation of environmental preservation, social accountability, and governance effectiveness in investment decisions. Choices and practical efforts [2]. Moreover, ESG offers companies self-assessment standards and acts as a crucial indicator for investors assessing sustainability[3]. Advancement and the realization of social accountability. ESG performance considerably affects the total worth and functional effectiveness of a business. In particular, robust ESG performance can significantly lower financing expenses, lessen the risks that companies encounter, and enhance their participation in foreign direct investment initiatives.

Nonetheless, adopting ESG practices requires extra financial commitments that can burden[3]. Monetary strain. Within the scope of a progressively interconnected relationship between digital technology and the actual economy, businesses need to adopt GDT to address and successfully address the difficulties of ESG practices [4]. GDT fundamentally reshapes conventional business models through the incorporation of new technologies. Like artificial intelligence and block chain. It enables expense minimization, productivity improvement and the generation of new possibilities for sustainable growth[5] [6]. Table 1 provides a summary research that has mainly explored the mechanisms of influence from various viewpoints like innovation, transparency of information, and costs of agency. In spite of these significant Insights and exploration regarding human capital have been quite restricted. Human capital, which includes the knowledge, skills, and abilities of employees, is a essential factor in organizational effectiveness and longevity. Acknowledging the significance Human capital's role in GDT and ESG performance is crucial. To acquire a thorough insight into the fundamental processes involved. As shown in table 1 below :

Table (1): Existing research on the influence of GDT on ESG performance

No.	Source / Author	Year	Independent Variable (IV)	Dependent Variable (DV)	Key Results & Findings
1	Alrawahna et al.[7]	2026	Strategic Digital Intelligence	ESG Performance & Sustainability	Digital intelligence significantly boosts the transition to renewable energy and ESG scores.
2	LSEG / Saudi Market Study	2025	Digital Maturity Level	Corporate ESG Ranking	Strong positive correlation between high digital adoption and "Environmental" pillar scores in Saudi firms.
3	Emirates Energy Council	2024	AI & Digital Twin Technology	Carbon Emission Reduction (E)	Digital Twins led to a 20% reduction in operational carbon footprint in O&G facilities.
5	Ebeh et al. (Regional)[8]	2026	IoT & Big Data Analytics	Supply Chain Governance (G)	Big data analytics enhances transparency and reduces corruption in energy procurement.
6	Vardopoulos et al.[9]	2026	Green Digital Innovation	Sustainable Firm Performance	Green innovation acts as a mediator, turning digital tools into measurable ESG outcomes.
7	Journal of Energy Econ.	2024	Blockchain Technology	Transparency & Reporting (G)	Blockchain prevents "Greenwashing" by providing immutable records of carbon credits.
8	Saudi Electricity Co.	2025	Smart Grid Digitalization	Energy Efficiency (E)	Smart grids improved energy distribution efficiency, contributing directly to ESG environmental targets.
9	Tech Sustainability J.	2025	AI-Driven Robotics	Occupational Safety (S)	Implementation of robotics in hazardous zones reduced workplace accidents by 15%.
10	International Policy Inst.[10]	2026	E-Government Integration	National ESG Performance	Regional digital integration helps national energy

	companies meet international ESG standards (NDC 3.0).

Our study examines energy companies operating in**(Iraq, Bahrain, Saudi Arabia, and the UAE)** during the period 20023 to 2026 as a sample group. The contribution of this study lies in its comprehensive approach to examining the links between corporate GDT, human resources, and ESG outcomes.

2. Research Problem

The world is currently witnessing a GDT across various fields and sectors, which has had positive and significant repercussions on the work environment, including social performance, the environment, and sustainability. This has prompted researchers to focus their research on GDT due to its crucial role in the workplace. The research problem revolves around the following question: What is the impact of green GDT on ESG Performance?

3. Research Hypotheses

1- There is a statistically significant positive relationship between green GDT and ESG performance in energy companies.

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2- Green Digital transformation has a statistically significant positive impact on ESG performance.

4. Study Objectives

1- To measure the relationship between green digital transformation and ESG performance in energy companies.

2- To test the impact of green digital transformation on ESG performance in energy companies.

5. Literature review

5.1 Green Digital Transformation

GDT involves incorporating digital technologies and formulating strategies, strategies and methods that enhance the value proposition and value development [11]. GDT, on one side, is viewed as a technological advancement. It likewise offers a competitive edge for the firm [12]. GDT empowers companies with an comprehension of combining diverse resources and enhancing productivity. These online resources turn into a competitive advantage since they are hard to replicate and limited in nature, precious, and hard to substitute [13]. As a result of GDT, companies have adopt a data-driven approach and leverage digital technologies to revolutionize production and service processes to boost operational efficiency, project management, resource use, professional tasks, lower expenses, and enhance performance [14]. The direct empirical evidence regarding the impact of (GDT) on performance remains quite inconsistent as, in the instance [15], certain positive elements exist, while, In the situation involving , there are no notable impacts on services. Such a gap suggests that the effectiveness of DT relies on complementary factors like green investment and strategic direction, which can be examined in the present study[16]. It is It is also important to note that the current study defines GDT as a prevalent process of adopting green digital capabilities, which is both distinct and similar to specific industries technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and robotics, and cyber-physical environments [17].

5.2 ESG Performance

ESG performance metrics are crucial for sustainable corporate advancement. Environmental efficiency includes multiple aspects, such as a business's ecological impact, resource use effectiveness ,and management of carbon emissions [18]. Social performance concerns the relationships between a company and its stakeholders including employees, customers, and suppliers emphasizing elements such as employee well-being, community involvement, and safeguarding human rights [19]. Governance effectiveness highlights the strength and clarity of a company's internal management processes, such as internal audit practices, risk management strategies, and board supervision22–25. Bekaert26 observed that companies with strong ESG ratings demonstrate greater consistent stock performance and exceptional long-term investment gains [20]. Furthermore, Doni27 discovered connections between ESG performance and innovation in corporations, employee contentment, and brand image, positively influencing financial and market outcomes. Consequently, ESG indicators serve as essential benchmarks for assessing sustainable development as well as essential elements for businesses seeking to obtain enduring competitive benefits and societal acknowledgment[21].

5.3 Digital Transformation and ESG Performance

Digital technology is crucial for the growth and administration of businesses. Processes, delivering strong technical assistance to improve ESG practices. Driving force of GDT, organizations utilize digital technologies comprehensively across multiple aspects of manufacturing, processes, and administration, thereby efficiently enhancing operational effectiveness, enhancing the standard of products and services, and encouraging success of new developmental frameworks[22]. Through the improvement of economic results, including financial circumstances, businesses not only gain the ability to bear social obligations but also foster the motivation to take initiative in fulfilling these obligations, thereby helping to enhance the company's image and reputation. Initially, the growth of the digital economy and digital finance has made things even more efficient[23]. Resource distribution, improved data integration and sharing abilities, along with enabling businesses to more effectively engage in green technology innovation. Additionally, the ease provided by digital technology has expedited the shift towards a sustainable industrial framework, while simultaneously reducing spatial carbon emissions and minimizing carbon footprints across areas[24]. Additionally, the GDT in both commerce and public services play a crucial role in enhancing energy security and reducing air pollution, especially in developing economies. Additionally, digital finance has shown its efficacy in reducing pollutant emissions, collectively emphasizing the crucial role of digital technology in improving environmental outcomes across different sectors Additionally, GDT improves corporate governance abilities, enabling companies to better reach their sustainability goals [25].

This is accomplished through the merging and sharing of essential information across various departments, minimizing ambiguity and doubt in innovation decision-making and enhancing the precision and effectiveness of evaluations[26]. Once the crucial digital assets and capabilities exist, companies can utilize them to enhance the distribution of digital assets throughout divisions, thereby enhancing internal oversight and tactical administration, ultimately fostering sustainable advancement [27]. Furthermore, to improve to meet stakeholder expectations, companies must proactively address environmental and social duties, providing extensive worth in domains like ecological management and social responsibility that goes beyond their outstanding financial results[28]. The extensive use of digital technology provides boards with effective data-gathering instruments and enhances knowledgeable decision-making procedures. At the same time, Digital technology reduces information asymmetry among board members, improving the efficiency and quality of decision-making[29]. With the adoption of digital technologies by businesses, changes in board

memberships are essential to meet the changing requirements. Requirements. Demands for varied skills and experiences promote diversity in sex, age, race, and tenure. Variety among board members. Digital technologies improve auditing and monitoring[30]. Processes, thereby facilitating stronger risk identification and evaluation while enhancing decision-making at all levels Furthermore, the effectiveness of digital technology in training auditing and oversight staff and improving their professionalism and responsibility warrants additional investigation[31].

During a time of increased examination from investors, regulators, and consumers, companies are beneath growing demands to showcase strong results in environmental, social, and governance dimensiones (ESG)[32] .Stakeholder theory suggests that a company's enduring success relies on its capacity to handle and address the anticipations of all its stakeholders, rather than merely shareholders[33]. In this context, (DGT) acts as an essential strategic enabler. through improved transparency and accountability, thus assisting companies in meeting diverse stakeholder expectations[34]. The impact of DGT on ESG outcomes expresses itself through three main avenues[35]. Initially, in governance, tools like block chain and Audit systems powered by AI greatly improve clarity of information and ability to track[36]. This lessens information imbalances and the potential for managerial self-interest enhance monitoring by regulators and institutional shareholders, and harmonizes corporate governance adhering to established standards [37]. Secondly, from an ecological viewpoint, the utilization of industrial IoT and sophisticated data analysis allows for immediate observation of energy use and carbon output [38]. These features enable accurate resource usage optimization and enhance predictive pollution management, assisting companies in adhering to environmental laws and minimize their environmental impact. The relationship between GDT and ESG Performance as shown in table 2 below:

Table 2: Relationship between Green Digital Transformation and ESG Performance

	Year	Author(s)	Study Title	Independent Variable (IV)	Dependent Variable (DV)	Main Findings
1	2026	Zhang & Wang [39]	Digital Catalysts: How AI and Cloud Computing Drive ESG Excellence in Manufacturing	Enterprise Digital Transformation	ESG Total Score	Digitalization significantly improves ESG performance by reducing agency costs and information asymmetry.
2	2026	Al-Amri et al.	The Social Impact of Automation: AI's Role in Enhancing Social Sustainability Metrics	AI-Driven Analytics	Social Responsibility (S)	AI tools enhance labor safety monitoring and diversity tracking, leading to higher Social scores.
3	2026	Khan [40]	Green Connectivity: IIoT Applications for Carbon	Industrial IoT (IIoT)	Carbon Emission Efficiency	IIoT adoption optimizes energy consumption, directly boosting the

			Neutrality and Environmental Ratings			"Environmental" component of ESG.
4	2026	Müller et al.[41]	Measuring Digital Maturity and its Correlation with Corporate Sustainability Reporting	Digital Maturity Levels	ESG Reporting Quality	Higher digital maturity correlates with more transparent ESG reporting and better stakeholder engagement.
5	2025	Liu & Sun	Trust in Data: Leveraging Blockchain for Immutable ESG Governance	Blockchain Technology	Governance Transparency (G)	Blockchain-based reporting minimizes data manipulation, significantly enhancing the "Governance" pillar.
6	2025	Kumar & Singh	Eco-Innovation in the Digital Age: A Path to Superior ESG Rankings	Digital Capability	Green Innovation	Digital capabilities act as a catalyst for green product development, improving overall ESG rankings.
7	2025	Rodrigue z et al.	The Cloud Benefit: Environmental Gains from IT Infrastructure Transformation	Cloud Computing Adoption	Operational Sustainability	Cloud migration reduces physical infrastructure footprint, aiding environmental sustainability goals.
8	2025	Zhao et al.	Big Data Analytics and the Future of Environmental Disclosure Compliance	Big Data Analytics	Environmenta l Disclosure	Big data enables firms to track and disclose environmental impact more accurately to regulators.
9	2024	Smith & Brown	Fintech for Good: Digital Finance as a Driver for SME ESG Performance	Digital Finance	ESG Performance in SMEs	Access to digital financial tools allows small firms to invest more in sustainable and social projects.
10	2024	Wang et al.	Smart Systems and Circular Economy:	Smart Manufacturing	Resource Productivity	Smart systems reduce waste and resource

			Impacts on Resource Productivity			depletion, driving a positive shift in ESG metrics.
11	2024	Nguyen et al.	Digital Supply Chains: Enhancing Ethical Auditing and Social Governance	E-Commerce Integration	Supply Chain ESG	Digital supply chains allow for better auditing of suppliers' ethical and environmental practices.
12	2024	Garcia & Silva	Digital Literacy at the Top: Boardroom Transformation and Corporate Governance	Digital Literacy of Board	Corporate Governance (G)	Boards with high digital literacy are more likely to implement robust ESG oversight mechanisms.

6 Results and discussions

6.1 Methodology

This research focused on major manufacturing firms in the energy industry across Iraq, Bahrain, Saudi Arabia, and the UAE. A snowball sampling technique was used, leveraging the alumni network and the entrepreneurs' group. Surveys were sent out electronically through Google Forms to pertinent staff members in the organizations involved in the research. To reduce the bias present in typical methodologies, the research took place in three primary stages: During the initial stage, data was gathered regarding background details and the perceived environmental, social, and governance (ESG) performance of the firms. During the second phase, information was gathered on business GDT and platform digitalization. During the third phase, information was gathered regarding green process innovation and green product innovation. The data collection process was finalized, with (774) questionnaires distributed and received back. Questionnaires that were returned were omitted because of incompleteness or various issues. The survey was developed using earlier research and employed a five-point Likert scale. Data analysis was conducted with the use of SPSS and Amos version 26 statistical software

6.2 Reliability and Validity

In this study, confirmatory factor analysis was conducted, resulting in a KMO value of 0.864 ($p < 0.001$); a KMO > 0.8 indicates effective factor analysis and a strong correlation among variables, which is ideal for this analysis. The cumulative sum of squares of rotating loads attributed to the first factor was 30.632%, falling short of the critical standard threshold of 40%, indicating the absence of common method bias. The Cronbach's α values for each variable in Table 3 exceeded 0.8, satisfying the reliability criteria.

Table 3: The Reliability of the Variables

Variables	Coding	Items	Cronbach's Alpha
Green Digital Transformation	GDT	14	0.94
(ESG) performance	ESG	15	0.88

To obtain the results, the first hypothesis, which states (There is a statistically significant positive relationship between green digital transformation and ESG performance in energy companies), was assessed. The data

(N:774) were analyzed using the SPSS statistical software for a sample of 774 participants. By calculating the correlation coefficient between variables as shown in table 4 below:

Table No. 4: Correlation Digital Transformation and ESG Performance

Variable Relationship	Correlation (r)	Significance (p)	Evidence Strength
Internal Consistency (GDL)	0.814 to 0.926	p<0.01	Very Strong: High reliability within digital items.
Internal Consistency (ESG)	0.583 to 0.630	p<0.01	Strong: Coherent measurement of ESG dimensions.
GDL1 ↔ ESG1	0.630**	p<0.01	Strong: Direct link between digital and green goals.
GDK2 ↔ ESG1	0.813**	p<0.01	Very Strong: High synergy in transformation.
GDL3 ↔ ESG4 (Capability)	0.861**	p<0.01	Very Strong: Digital tools drive Governance.
GDL4 ↔ ESG5 (Capability)	0.754**	p<0.01	Strong: Digital maturity boosts Social/Env performance.
Specific Mappings	0.342 to 0.397	p<0.05	Moderate: Specific niche associations.
Outliers (GDL1 ↔ GDL11)	-0.011	Not Sig.	Negligible: No meaningful negative relationship.

To obtain more exact results, the data was assessed a second time and in a second stage in the Amos statistical program, which showed that some data needed to be changed to obtain right results, as shown in Figure (1):

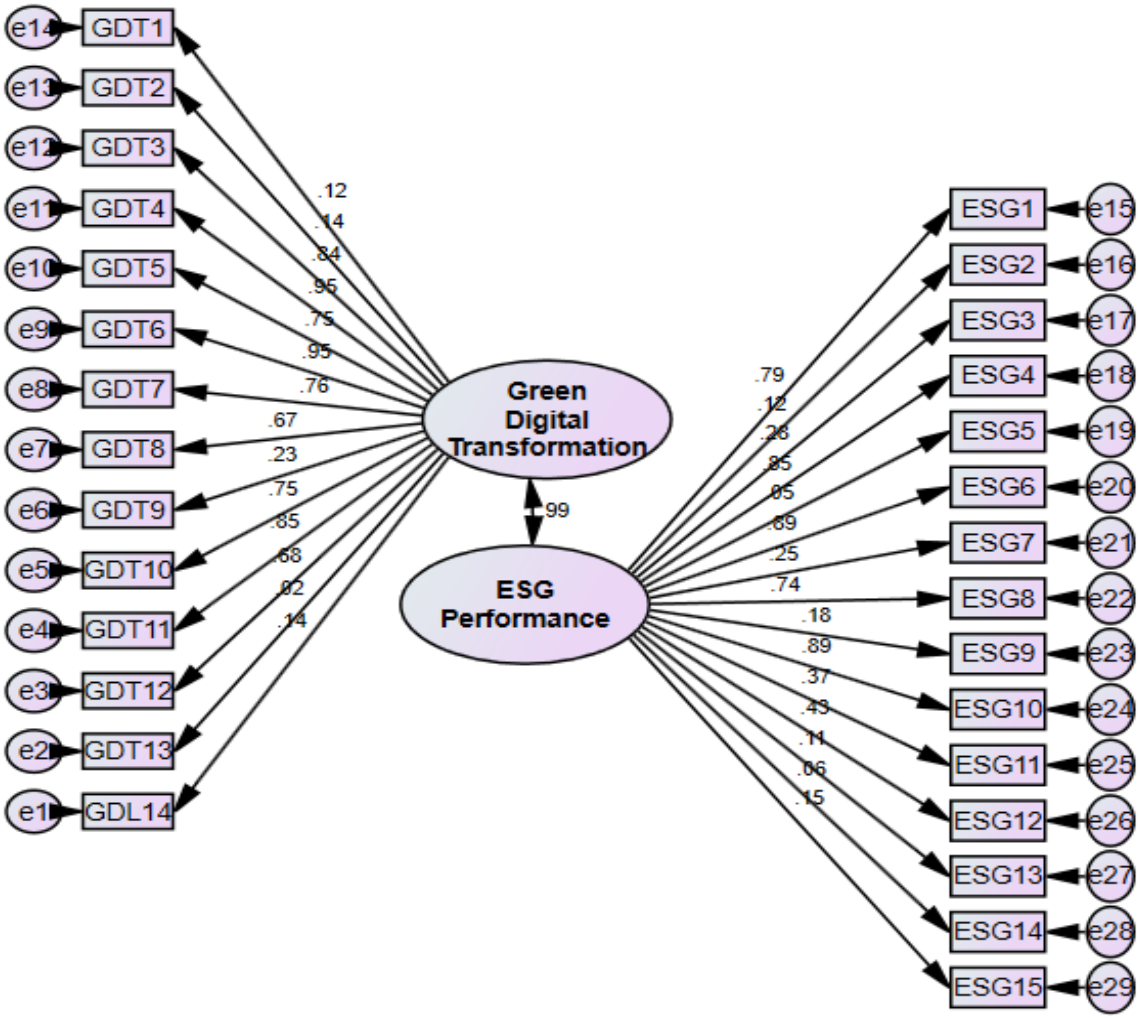


Figure (1): measurement of the Green Digital Transformation and ESG Performance

To obtain more right results, the data was tested again in the Amos program after adjusting according to Amos scientific standards in Figure 2 . This shows that the effect factor, which was less than (0.5) in the first figure, was removed. Some items in the two variables, GDT and ESG Performance, all quality standards for the Amos are acceptable(CFI,IFI,AGFI,ITI), as they are all higher than (0.90). were removed. Therefore, acceptable and reliable results were obtained, as all items had an effect factor higher than (0.5), This supports the second hypothesis, which says that GDT has a statistically significant positive impact on ESG performance). as shown table (5) and in Figure 2 below:

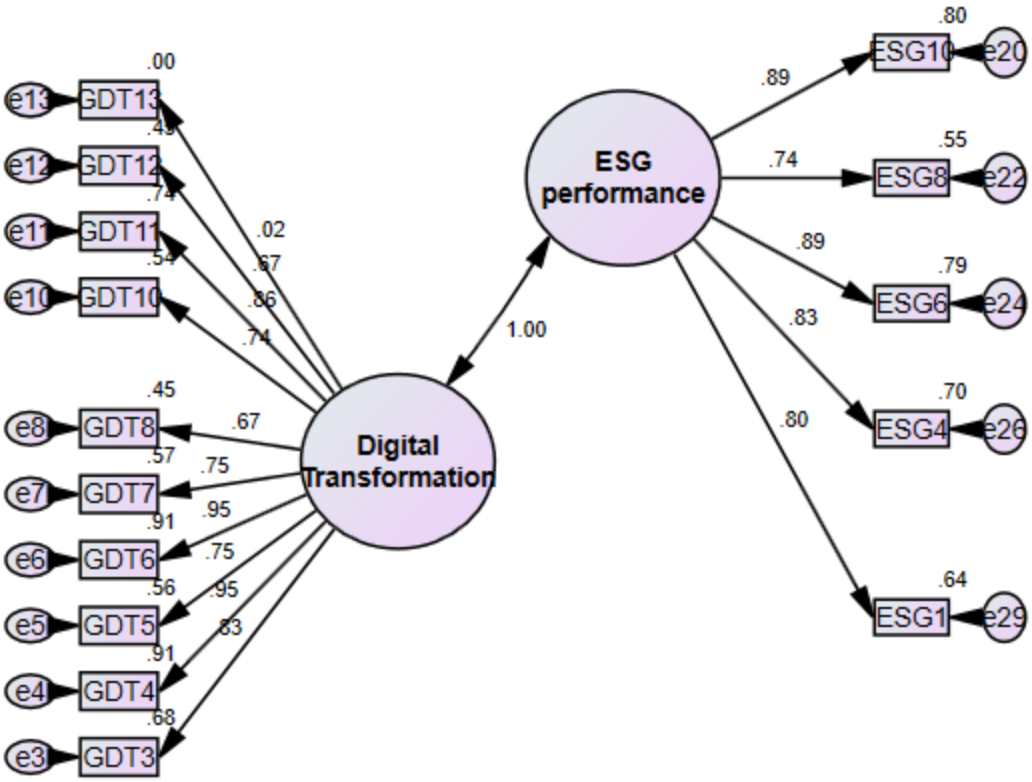


Figure (2): measurement of the GDT and ESG Performance after modification

Table no. 5: Regression Weights GDT in ESG Performance

			Estimate	S.E.	C.R.	P	Label
GDT3	<---	Digital_Transformation	1.309	.062	21.112	***	
GDT4	<---	Digital_Transformation	1.527	.065	23.641	***	
GDT5	<---	Digital_Transformation	1.204	.062	19.462	***	
GDT6	<---	Digital_Transformation	1.518	.064	23.692	***	
GDT7	<---	Digital_Transformation	1.163	.059	19.645	***	
GDT8	<---	Digital_Transformation	1.092	.062	17.612	***	
GDT10	<---	Digital_Transformation	1.062	.056	19.072	***	
GDT11	<---	Digital_Transformation	1.294	.060	21.738	***	
GDT12	<---	Digital_Transformation	1.000				
GDT13	<---	Digital_Transformation	.037	.054	.679	.497	
ESG10	<---	ESG_performance	1.265	.049	26.024	***	
ESG8	<---	ESG_performance	1.000				
ESG6	<---	ESG_performance	1.296	.050	25.799	***	
ESG4	<---	ESG_performance	1.140	.047	24.222	***	
ESG1	<---	ESG_performance	1.027	.045	22.942	***	

6.3 Theoretical Analysis

a) Environment

At the ecological level, a business will inevitably generate different types of environmental pollution effects. Throughout the production and manufacturing process. The company must incur expenses to counterbalance the pollution. Brought about by itself to the surroundings. In the realm of DX, organizations can implement advanced digital solutions. Technologies like AI and big data to boost efficiency, perform accurate production, and promote sustainability innovative abilities to decrease ecological contamination [42]. Moreover, DX encourages the the rise of network data sharing platforms, enabling companies to explore and analyze diverse data to anticipate shifts in policy trends, improving the communication exchange among the internal management team and the external regulatory landscape, enabling the company to more effectively modify its production strategies, product guidelines, and so forth, in line with policy developments and enhance its effectiveness in the ecological area[43].

b) Social Responsibility

Many companies typically enhance their image and presence through participation in business and community service initiatives. In the digital age, this effect has become even more pronounced, as GDT encourages the emergence of online data-sharing platforms, which companies use to build relationships with potential collaborators and business customers[44]. External organizations, such as governments, can more easily collect data to assess the impact of an organization's efforts [45]. As a result, companies are increasingly inclined to disclose their various corporate social responsibility (CSR) initiatives in order to improve their CSR performance.

c) Corporate Governance

The effectiveness of corporate governance indicates if a company is able to satisfy the demands of different interested parties. The DX can transform the economic environment and operational circumstances within the organization into data and transform the requirements and anticipations of staff, outside investors, etc., via cloud aggregation into information[46]. A business can more effectively fulfill the demands and expectations of its workers and outside stakeholders by examining this information. External investors and employers can easily understand the operational status of each. Business using data, thus enabling more accurate choices in hiring and investment. Furthermore, digital technology can detect financial irregularities and weaknesses instantaneously, enhance adherence to corporate governance [47].and enhance corporate governance effectiveness organically

7 Conclusion

According to the findings mentioned, it can be concluded that digitalization positively influences environmental, social, and governance (ESG) performance, both directly and via indirect effects. This indicates that as digitalization grows in the specified countries, it has a favorable effect on ESG performance in all involved nations. These results emphasize the interrelation and possible advantages of embracing digitalization for sustainable development and ethical business practices worldwide, especially in the energy industry. Based on the findings mentioned above, the ensuing policy suggestions can be provided:

1. Policymakers must focus on efforts to close the digital divide and guarantee equal access to digital technologies and services. This entails offering low-cost internet services and programs for digital literacy[48] . Through the advancement of digital inclusion, nations can create a more fair and inclusive digital community .

2. Governments ought to encourage the establishment of strong digital infrastructure , including fast internet access, dependable data networks, and sophisticated technology platforms[49]

3. Decision-makers in Arab and Gulf nations must focus on enhancing and broadening digital public services for both enterprises and individuals. This encompasses digital platforms for e-government services, online business registration, electronic tax submission, and access to digital resources, healthcare, and education[50]. Countries can boost their efficiency, transparency, and sustainability by simplifying administrative processes, minimizing bureaucracy, and enhancing access to vital services.
4. Pursuing policies that draw and support skilled and experienced talent in the energy sector is crucial. This involves lowering trade obstacles, simplifying international digital transactions, and promoting global collaboration[51]. This will encourage the sharing of knowledge, technology, and sustainable methods, resulting in better environmental, social, and governance (ESG) outcomes through increased global cooperation.
5. Nations ought to keep enhancing suitable frameworks to foster an appealing atmosphere for eco-friendly investments and sustainable business activities. This involves enacting favorable policies like tax breaks, subsidies, and regulations that promote clean energy, efficient resource usage, and eco-friendly technologies[52].

Although the findings are significant, this research could be enhanced in these specific areas:
Although the paper suggests a link between GDT and ESG performance, it's crucial to remember that correlation does not mean causation. The research does not confirm a causal link between digitalization and enhanced ESG performance, since other variables may be influencing these outcomes. The Gulf region and Iraq display different degrees of economic growth, digital preparedness, and ESG outcomes. Variations among nations can add extra complexities and subtleties that the analysis might not completely encompass. Additional research would necessitate broadening the range of control variables that might impact the outcomes. Moreover, sensitivity analyses are required to evaluate the strength of the results against possible confounding factors

Declarations

Ethics, Consent to Participate, and Consent to Publish declarations: *not applicable.*
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Data Availability :"The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request"
Ethical Approval and accordance "The study received ethical approval from the Kingdom University Ethics Committee, Bahrain. All research procedures were performed in accordance with the ethical guidelines and regulations of Kingdom University and the principles outlined in the Declaration of Helsinki".
Informed Consent "Informed consent was obtained from all individual participants (professionals and stakeholders in the energy sector) included in this study".

Consent to publish "Informed consent for publication of the results and any associated data was obtained from all individual participants included in the study".

Consent to participate Informed consent was obtained from all individual participants included in the study

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