P-ISSN: 2709-6254	Journal of Development and Social Sciences	October-Dec 2024, Vol. 5, No. 4
O-ISSN:2709-6262	https://doi.org/10.47205/jdss.2024(5-IV)35	[396-415]

Journal of Development and Social Sciences
www.jdss.org.pk

RESEARCH PAPER

Environmental Performance in the Era of Industry 4.0: The Role of Corporate Digital Responsibility, Green Capability, and Environmental Dynamism

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ABSTRACT

The objective of this study is to investigate the relationships between corporate digital responsibility and the ability of businesses to accomplish environmental goals. In addition, we investigate how environmental dynamics improve environmental performance. Although corporate digital responsibility has been shown to improve operational and financial performance, there may be unanticipated environmental consequences. To address these concerns, this paper investigates how firms might build a portfolio of technologies to achieve their corporate digital responsibility (CDR) goals. It refers to the companies' ability to execute digital corporate responsibility. Close ended questionnaire was used. A survey of 319 Pakistani manufacturing firms revealed a significant correlation between corporate digital responsibility and environmental performance. The data support the premise that green competence mediates the link between corporate digital responsibility and environmental performance. The results do not support the hypothesis that the usage of environmental dynamism moderates the association between corporate digital responsibility and environmental performance. We suggest employing a mixed-methods strategy that combines both in-depth qualitative research and advanced quantitative analyses. As a result, companies are unable to utilize the synergies between CDR and environmental dynamism to achieve higher levels of EP.

KEYWORDS Corporate Digital Responsibility, Environmental Dynamism, Environmental Performance, Green Capability

Introduction

The environment is a complex domain that has significant consequences for both human well-being and the natural world (Chatterjee et al., 2024). The environment provides us with essential natural resources for survival, and we can influence it through our actions and behavior (Jia et al., 2024; Asiaei et al, 2022). The manufacturing industry has a big effect on the environment, and many manufacturing firms are taking steps to reduce the damage they do to the environment. The amount of energy used to power the production process and move materials around is one of the most significant environmental problems of manufacturing firms, such as air pollution, carbon emissions, and water pollution that endangers the survival of life on earth (Bocquet et al. 2019). Therefore, it is crucial to prioritize promoting environmental performance before addressing global issues that both academics and practitioners are concerned about (Galan & Zuñiga-Vicente, 2022).

This has raised concern for manufacturing firms to start using more environmentally friendly methods, including digital technologies, to lower their impact on the environment (Bradu et al., 2022). Corporate digital responsibility is a combination of digital technology and corporate social responsibility. It includes a mix of actions and behaviors that help firms use information while using digital technology in ways that are beneficial for society, the economy, and the environment (Cheng & Zhang, 2023). Corporate digital responsibility can make the planet happier! How? We advocate for energy-efficient technology, use data to manage resources efficiently and encourage environmentally friendly practices like recycling electronic waste. Furthermore, it allows for remote and online collaboration. This helps cut down emissions from travel. In short, CDR encourages new ideas and raises awareness for better results for our environment (Bocquet et al. 2019).

Previous studies have investigated corporate digital responsibility across various domains such as human-technology relations (Suchacka, 2020), the hospital industry (Jones & Comfort, 2021), artificial intelligence (Elliott et al., 2021), social sciences (Suchacka, 2019), sustainability and the digital age (Herden et al., 2021), and construction engineering (Weber-Lewerenz, 2020), there remains a significant knowledge gap to understand the effect of corporate digital responsibility on environmental performance (Úbeda-García et al., 2022). No research has thoroughly examined the direct influence of CDR on environmental performance, despite the increasing importance of digital responsibility in business activities (Úbeda-García et al., 2022).

This link is critical because it has a significant impact on sustainable growth, particularly in sectors that are rapidly adopting advanced technologies. Having such recognition, manufacturers must stay informed and adapt their strategies to leverage these technologies to enhance their environmental performance and overall competitiveness (Upadhyay et al., 2021). A comprehensive analysis of the impact of CDR on EP is an essential and inadequately studied domain that necessitates additional inquiry. This concern was further stressed by the sixth IPCC. They have called for a climate emergency, claiming that our atmosphere has the highest concentration of carbon dioxide, global warming is expected to reach 1.5C, and there is only a small amount of carbon left (6th IPCC Assessment Report, 2023).

They emphasize that while selecting their digital technology portfolio, companies should evaluate the environmental implications Asiaei et al. (2022). To address this highlighted gap, the present study aims to investigate the effect of corporate digital responsibility on environmental performance in Pakistan's manufacturing context. In addition, research argues that while corporate digital responsibility may have a positive effect on environmental performance, the specific mechanism by which and why this relationship is established is not clear (Bradu et al. 2022).

The term "green capabilities" refers to a company's ability, resources, and procedures for incorporating environmental sustainability into its business operations. Organizations that have strong green capabilities may effectively translate their CDR ambitions into measurable environmental outcomes. For example, the use of digital technology, such as corporate digital responsibility, allows firms to improve the usage of resources, decrease waste, and reduce carbon emissions. These activities are crucial for increasing energy efficiency and lowering environmental footprints across a wide range of businesses (Zhang, & Li, 2024). Thus, green capabilities serve as a mediator between the relationship of CDR and EP, contributing as a second major objective of this study.

Furthermore, it is imperative to examine the influence of ED on the relationship between CDR and a firm's environmental performance, as it is contingent upon a variety of external factors. Environmental dynamism, defined as the rapid evolution of markets and production environments, influences firms' strategy adaptation (Bradu et al. 2022). This research suggests that ED moderates the relationship between CDR and firm environmental performance, thereby enhancing understanding of how external environmental factors influence organizational success in dynamic environments. Consequently, this study's third significant contribution stems from the moderating effect of environmental dynamism on the relationship between CDR and EP (Zhang & Li, 2024).

Overall, this study adds value to the environmental performance literature in three significant ways, particularly in Pakistan's manufacturing firms, which use natural resource-based view (N-RBV) theory and information processing theory (IPT) as their overarching theoretical frameworks (Peterson et al., 1991). This study first explores the relationship between corporate digital responsibility and environmental performance in manufacturing firms, emphasizing the role of digital technology in enhancing sustainability as supported by the NRBV theory. Hart (1995) contended that in order to meet the challenge of global sustainability, firms may need to reduce their material and energy consumption in developed markets while expanding into developing ones. Clean technology plans address how firms develop new capabilities and position themselves to gain a competitive edge as their industries change.

Second, this study proposes GC as a mediator that clarifies how corporate digital responsibility influences environmental performance, linking organizational resources to better sustainability outcomes. Better environmental performance is mostly driven by green capabilities, which include proactive environmental practices, sustainable product innovation, and effective resource management. By using techniques like energy-efficient technologies and cleaner production procedures, these skills enable businesses to lower waste, energy use, and emissions. Throughout the product lifecycle, businesses reduce their environmental effect by implementing sustainable product designs and ethical sourcing practices. When it comes to managing and utilizing environmental resources in a way that is consistent with environmental responsibility and sustainability, GC is an essential ability.

Third, the research contributes to demonstrating a moderating effect of environmental dynamism in the context of information processing theory (IPT) (Peterson et al., 1991). It emphasizes the contingent relationship between environmental performance and corporate digital technology, recommending the addition of a moderating variable. Information processing theory suggests enhancing information processing capabilities in dynamic manufacturing environments, characterized by swift changes and short product life cycles. Consequently, information processing theory recommends that businesses modify their information expertise infrastructures to accommodate this environmental dynamism (Tekala et al., 2024).

Furthermore, the study's objective also fulfils Sustainable Development Goals (SDGs), i.e., Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development. Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation (Agenda for Sustainable Development Goals 2030). This study will assist manufacturing industries in selecting their digital portfolio and developing strategies that align with it (Hamid et al., 2022). The state's environmental policymaking can benefit from the study's findings. The study's findings can establish a benchmark for manufacturing firms, highlighting the crucial role their organizations play in the environment, and providing guidelines for all manufacturing organizations to follow. It will deal with the issue of manufacturing firms' environmental performance (Majid et al., 2022).

This study offers a methodological contribution, as previous research on CDR solely relied on a qualitative approach rather than a quantitative one. Previously, corporate digital responsibility has been checked with human-technology relations (Suchacka, 2020), the hospital industry (Jones & Comfort, 2021), artificial intelligence (Elliott et al., 2021), social sciences (Suchacka, 2019), sustainability and digital age (Herden et al., 2021), and construction engineering (Weber-Lewerenz, 2020). The association between corporate digital responsibility (CDR) and EP has not been demonstrated in any quantitative research (Úbeda-García et al., 2022). Researchers have defined and studied CDR in many settings but usually focused on case studies and theoretical discussions.

Literature Review

Theoretical Background

Information Processing Theory (ITP)

Galbraith (1973) created the notion of information processing theory (IPT) to help with the development of organizational structures. The configurations of resources, technology architecture, and other work units that facilitate information collection, processing, and distribution are known as information processing capabilities, while the various environmental contexts in which the firm operates determine its information processing needs (Peterson et al., 1991). Aligning information processing demands and resources with information processing theory is critical for optimal performance. Focus on resource configurations and environmental contexts (Asiaei et al., 2022)

Natural Resource-Based View

Hart (1995) broadens the concept of the resource-based view to include the fact that firms that are overly dependent on a particular set of resources may struggle to obtain other resources or extend their operations. Because of the demands placed by the natural environment, the natural resource-based view NRBV of the firm is an adaptation of the RBV of the firm. The interconnection and complexity of environmental issues will put the corporate community under pressure to go beyond merely adhering to environmental laws and offer creative solutions to environmental concerns (Hart, 1995). Particularly when it comes to sustainability and environmental performance, the NRBV highlights the significance of natural resources and environmental capabilities as critical strategic assets that can support a company's long-term success (Asiaei et al., 2022).

Hypotheses Development

Corporate Digital Responsibility and Environmental Performance

Climate involves many natural factors and environmental issues, such as air and water pollution, carbon emissions, and waste. The world is now powerless to prevent tragedies and calamities due to natural conditions. By effective information processing, digital technologies assist the choices made in production planning and management, which may improve operational effectiveness, lower costs, and boost profitability (Weber-Lewerenz 2020). According to the NRBV framework, CDR is a collection of competencies and procedures that a firm establishes to properly manage its digital resources and technology by the values of ethical and sustainable business practices (Cancino et al. 2018). Firms set up the Internet of Things, cloud computing, big data, and analytics as part of an advanced manufacturing system to gather and analyze information about production and operations more efficiently and effectively (Bradu et al. 2022).

When considering NRBV, Environmental Performance can be seen as an essential attribute and a collection of practices that help manufacturing firms use environmental resources effectively while reducing adverse environmental effects (Castelo-Branco et al. 2022). It entails creating competencies in line with sustainable practices and using them to gain an edge over competitors. To share data and interact with one another, tags, sensors, actuators, and other physical components are heterogeneously networked within plants thanks to the Internet of Things (Herden et al. 2021). Including environmental concerns in product development and production makes things more complicated because firms need to follow stricter rules, use eco-friendly materials, reduce waste, and lower emissions. This often requires new technologies, processes, and sometimes higher costs, making decision-making and operations more challenging (Upadhyay et al. 2021).

Digital technologies can provide effective solutions for environmentally friendly product design, manufacture, and servicing procedures that reduce the use of natural resources and harmful pollutants over the whole product life cycle (Chaudhary, 2019). The Internet of Things, cloud-based design, and big data analytics improve information flow management and enable green product creation and Eco-design innovation (Li et al. 2020). The N-RBV framework regards EP and CDR as key resources and competencies that firms cultivate and use to obtain a competitive edge (Hart, 1995). In the competitive business world, firms that successfully manage their digital footprint ethically and perform well in terms of environmental sustainability will be in a better position to build long-term success and sustainable value (Upadhyay et al., 2021).

Digital technology that doesn't follow corporate social responsibilities cannot shape the rules and values of CDR. This means responsible use of technology is necessary for a firm to have digital responsibility (Mueller 2022). Firms that successfully build CDR capabilities can use them to maximize digital resources while upholding moral and appropriate usage of the internet. In the same way, building capacities in line with environmental performance enables manufacturing firms to effectively utilize environmental resources, cutting expenses and risks related to pollution (Mueller, 2022). These new technologies brought about several beneficial changes, such as an increase in people's quality of life. Such as environmental deterioration and social inequality. Today's cultures are faced with a similar situation as the new digitization emerges, providing both opportunities and risks (Lobschat et al., 2021).

H1: The firm achieves environmental performance through corporate digital responsibility.

Corporate Digital Responsibility (CDR) on Green Capability (GC)

CDR orientation imitates an organization's deliberate plan to reconfigure its operational framework, procedures, structure, and operations in order to lessen the negative impact of its practices on the natural environment. Within the framework of the NRBV (natural Resource-Based View) paradigm, CDR and GC are both essential components that support a firm's sustainability and competitive advantage. The relationship between responsible digital practices and a firm's capacity to create and use green capabilities helps explain how CDR affects GC. GC refers to an organization's capacity to manage and utilize environmental resources sustainably (Zhang & Li, 2024).

Within the framework of the NRBV (natural Resource-Based View) paradigm, CDR and GC are both essential components that support a firm's sustainability and competitive advantage. The relationship between responsible digital practices and a firm's capacity to create and use green capabilities helps explain how CDR affects GC. It involves implementing practices that reduce environmental impact, such as minimizing waste, conserving energy, and using sustainable materials. By integrating GC, businesses align their operations with environmental responsibility, balancing growth with ecological protection. Previously most of the research has shown that firms' environmental-related, goals and strategies have an approving impact on environmental performance (Cheng & Zhang, 2023).

This approach helps safeguard resources for the future while supporting long-term sustainability goals. CDR is a collection of practices and skills that a manufacturing firm adopts to manage its digital assets sustainably and ethically. GC is significantly impacted by CDR in the context of the NRBV framework. In the context of environmental sustainability, CDR practices can provide a competitive advantage, innovation, and responsible resource management, all of which can have a favorable impact on a firm's capacity to develop and employ green capabilities (Zhang & Li, 2024). The Firms that believe in a sustainable environment greatly participate in CDR practices to enhance environmental performance. According to published research, a set of corporate responsibilities which firms practice, consists of dynamical characteristics that promote sustained environmental performance (Weber-Lewerenz 2020).

H2a: The firm achieves green capability through corporate digital responsibility.

Green Capability and Environmental Performance

The greatest choice for organizational survival in today's fast-changing environment is to have green capabilities that can achieve a sustainable competitive advantage and exceptional performance. While many academics talked about dynamic capabilities, green capabilities have received less attention. The concept of "green capability" focuses on integrating, building, and re-configuring internal and external resources for environmental protection (Yousaf 2021). According to the Natural Resource-Based View (NRBV), the impact of GC on EP is critical in understanding how a firm's strategic resources and skills in managing environmental elements contribute to its overall performance. GC is regarded as a vital strategic asset that significantly enhances a firm's environmental performance in the context of the Resource-Based View (NRBV).

Strong green capabilities enable manufacturing firms to take proactive measures to solve environmental issues and take advantage of sustainable business prospects. According to the literature, organizational competencies greatly boost firms' performance. Furthermore, according to the natural RBV theory, having a strong green capacity might be a key indicator of improved environmental performance (Hart, 1995). Firms that are strong in green capability increase a firm's capacity to innovate and create innovative, environmentally friendly goods, processes, and technology. Manufacturing firms may improve their environmental performance by adjusting to shifting consumer preferences, market demands, and environmental legislation. Developing extensive green skills can provide firms with an edge over others (Úbeda-García et al. 2022).

Businesses that do well in terms of the environment may draw in environmentally sensitive customers, find it easier to comply with strict environmental laws, lower expenses related to waste and inefficient use of resources, and improve their reputation as socially conscious firms. Green process, product, and service innovation, the researcher believes, should be proactive efforts targeted at reducing or eliminating negative environmental effects in order to improve environmental performance (Úbeda-García et al. 2022). GC has a major influence on EP inside the NRBV framework. Firms that cultivate and utilize significant green competencies are more advantageous positioned to enhance their environmental performance, secure a competitive edge, engage in sustainable innovation, and create lasting sustainability through efficient environmental impact management.

H2b: The firm achieves environmental performance through green capability.

The Moderating Role of Environmental Dynamism

The environment is made up of many uncontrollable factors that present opportunities and challenges for firms as they work to achieve their goals. Organizations must continuously adapt to the constantly changing external firm environment in which they compete (Rezai et al., 2020). Digital technology advancements and rising competition have created highly dynamic conditions for firms. The degree of volatility or unpredictability of change within a sector is referred to as environmental dynamism (Dess & Beard, 1984). Several factors can influence industry advancements, such as the rate of change and innovation in the firm's core activities, the introduction of new goods and services, and the ambiguity or unpredictability of rivals' actions and client preferences (Yang & Li, 2011). Firms that operate in volatile environments must deal with quick changes in technology, client wants and preferences, and competition (Simerly & Li, 2000).

Increased causal uncertainty, which makes it harder for rivals to copy specific resources or resource combinations, helps firms gain a competitive edge in unpredictable and volatile settings. The firm's competitive position will benefit from the match between the operational capacity and the environmental requirements (McArthur & Nystrom, 1991). Depending on how firms align themselves with their firm's environments, operations competence has a variety of effects on competitive advantages and performance (Li et al., 2020). For firms to increase the productivity of their operations in a dynamic environment, operations capacity that senses market changes and responds to adjustments will be increasingly useful. In a highly dynamic environment, operations capacity and productivity will be more correlated than in a low-turbulence (Agyapong et al., 2019).

In environmental management, environmental dynamism has frequently been highlighted as a contextual issue (Chan et al., 2016). To attain high performance, firms should base the design of their organizational structure on the marketplace they compete in. Manufacturing firms are characterized by a high level of dynamism, which results in huge information processing in industrial contexts with short lifespans of products and frequent changes in demand, manufacturing, and laws (Li et al., 2020). In addition, firms modify their information technology infrastructures to keep up with environmental dynamism. Manufacturing firms unfortunately cannot exclusively rely on the organizational border for data or information gathered within the corporate border in a dynamic environment (Yang & Li, 2011).

According to Pagell and Krause (2004), environmental dynamism, often known as the instability of a firm's environment, has been recognized as a contextual component in the domains of operations management and environmental management. The firm is more likely to expand the use of digital technology into expansion activities when confronted with high levels of environmental dynamism (McArthur & Nystrom, 1991). In order to attain high performance, firms are encouraged to model their organizational structures upon the industry they operate (Hartmann & Vachon, 2018). As a result, environmental dynamism implementation would have a stronger impact on the relationship between corporate digital responsibility and environmental performance.

Environmental dynamism describes the speed and unpredictable nature of changes occurring in the external environment. This concept is part of the Information Processing (IP) theory, which examines how organizations collect, analyze, and utilize information to adjust to their surroundings (Peterson et al., 1991). To understand how Environmental Dynamism influences the connection between EP and CDR, it is essential to consider several factors. Situations characterized by environmental dynamism often require organizations to quickly adapt to changing conditions. Firms operating in such dynamic environments are compelled to adopt CDR practices that are more flexible and responsive (Asad et al., 2018). In a highly dynamic environmental context, there may be a greater demand for improved environmental performance. Organizations in these situations must adhere to higher expectations set by regulators, investors, and consumers regarding their sustainability efforts (Tekala et al., 2024).

The development and implementation of digital solutions aimed at enhancing environmental performance may be affected by environmental changes. Strong principles of CDR enable manufacturing firms to efficiently track, evaluate, and improve their environmental impact by investing in digital tools and technologies (Li et al., 2020). By utilizing digital platforms for sustainability reporting and monitoring, firms can better adapt to evolving environmental requirements. The Information Processing (IP) theory suggests that Environmental Dynamism accelerates the connection between EP and CDR by encouraging the creation of digital sustainability solutions, promoting the adoption of flexible CDR practices, enhancing environmental responsiveness, increasing strategic agility, and sometimes providing a competitive advantage to firms that effectively navigate the changing environmental landscape (Orbik & Zozuľaková, 2019).

H3: Environmental dynamism accelerates the relationship between corporate digital responsibility and environmental performance.

Based on these hypotheses, a conceptual framework/model has been developed, as depicted in Figure 1.

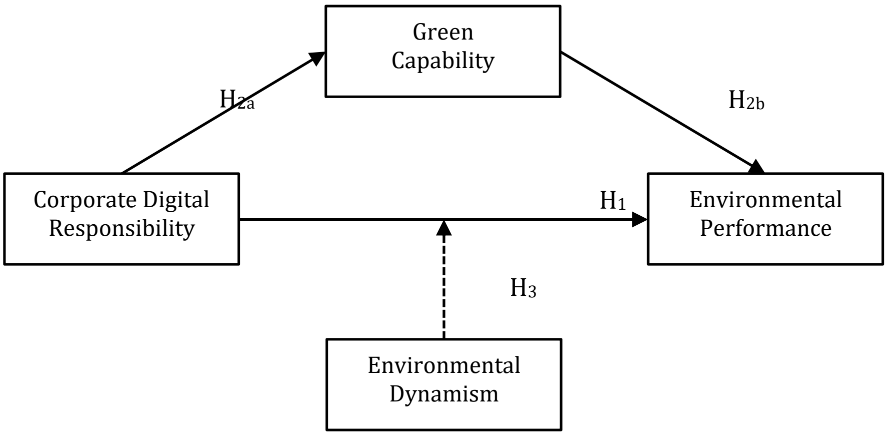

Figure 1: Research Model

Material and Methods

Sample

This research was explanatory which evaluates our research hypotheses through quantitative approaches (Chwiłkowska-Kubala et al., 2021). We developed a survey aimed at collecting data from respondents regarding their industry type, the location of their firms concerning Industry 4.0 technology, their implementation of environmentally friendly practices, and their objectives related to CDR. The questionnaire underwent pretesting with a group of experts comprising professors, PhD students, professionals, and managers. We sought their feedback on clarity, readability, and comprehensiveness. Based on their input, the survey was refined and improved accordingly (Florey, 1993).

The data collection process commenced with the distribution of a survey to an initial sample of 84 managers from various firms. These managers were contacted via email and WhatsApp, which included an online link to the questionnaire hosted on Google Forms, and a few through personal visits. Within 11 weeks, a significant portion of responses was received. Ultimately, we gathered a total of 319 usable observations after excluding any deemed invalid.

The study primarily focused on manufacturing firms in Pakistan. Our respondents were operational managers, senior managers, and top management predominantly in manufacturing firms that utilize digital technologies. The findings highlight a diverse industrial landscape, with textile and apparel at 23.44% followed by pharmaceuticals at 13.02%, automobile manufacturing comprising 6.25% of respondents, followed by electrical and electronics at 9.38, and agricultural-related firms at 9.11%. More detailed insights into respondent distribution and sample characteristics are presented in Table 1.

Table 1
Demographic Profile

Particulars	Frequency	Percentage
Respondent Designation	84	21.88%
Manager or Senior Manager	57	14.84%
General Manager	55	14.32%

Operational Manager	56	14.58%
CEO	84	21.88%
Owner/ Co founder	43	11.20%
Board member/ Partner	5	1.30%
Sindh	57	14.48%
Punjab	281	73.18%
Balochistan	12	3.13%
KPK	30	7.81%
1-5 years	49	12.76%
6-10 years	61	15.89%
11-15 years	39	10.16%
16-20 years	79	20.57%
more than 20 years	154	40.10%
Textile and apparel	90	23.44%
Pharmaceutical	50	13.02%
Electrical Equipment	36	9.38%
Computer hardware, robot and AI machines	118	30.73%
Cement building, wood, paper, and board	22	5.72%
Agricultural related companies	35	9.11%
Automobile manufacturer	9	2.34%

Measurements

The questionnaire was divided into two parts: the first part was for analyzing the demographic data that includes firm size, firm location, firm age, and industry type. In order to measure environmental performance, these demographics were relevant (Yu et al., 2022). The second part of the questionnaire was used to analyze the study variables. All measurements were taken on a Likert scale of 1 to 5, with 1 indicating "strongly disagree" and 5 indicating "strongly agree" (Tylavsky & Sharp, 1995). Items regarding CDR scale developed by Hustvedt and Kang (2014) and consisting of 5 items were adopted. The study adopted 6 components of environmental performance from Zhu and Sarkis, (2004). The study adopted 4 measures for environmental dynamism created by Miller and Friesen (1982) and Jap (1999) and adopted 4 items of environmental dynamism from Khandwalla, (1977). The study uses 7 items of green capability created by Pavlou and El Sawy (2001).

To assess the potential "non-response bias," we employed several methods. Initially, we compared early respondents (those completing the survey first) with late respondents (those completing it later). A one-way analysis of variance (ANOVA) revealed no significant differences across all survey items between these groups. These results suggest that "non-response bias" is not a significant issue in this study. We also looked at demographic factors like company size, location, age, and industry type to check for non-response. Again, our analysis showed no big differences among these groups. This supports the idea that non-response bias isn't affecting our study's results. For example, we split the 'industry type' into two categories: one group included automobile & textile industries, while the other covered pharmaceuticals and cement companies, as given in Figure 1. We did an ANOVA along with Fisher's F-test for these groups. The results gave us probabilities of 0.172 for profits, 0.521 for ROI, 0.469 for cost savings, 0.693 for energy costs, and 0.498 for environmental impact. These results mean the averages of both groups are pretty similar. We noticed the same trends with all other variables and descriptive statistics.

Results and Discussion

Measurement Model

The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). PLS-SEM is good for looking at complex models with many factors, including how different factors influence each other. It's known for being powerful and efficient in estimating parameters and predicting results, which makes it a good fit for this research. PLS-SEM was selected because the model incorporates higher-order factors and a moderator, making other methods appropriate. Additionally, prior research has indicated that PLS-SEM is effective with data obtained from non-probability samples. In evaluating the measurement model, we looked at two types of validity: convergent and discriminant. We also checked the reliability, known as composite reliability. As shown in Table 2, all constructs had a composite reliability above 0.70.

Table 2
Construct Reliability and Validity

Construct	Items	VIF Values	Outer Loading	Composite Reliability (CR)	Average Variance Extracted (AVE)
Corporate Digital Responsibility	CDR1	4.310	0.230	0.891	0.693
	CDR2	3.088	0.241		
	CDR3	5.805	0.228		
	CDR4	6.466	0.236		
	CDR5	3.596	0.267		
Environmental Dynamism	ED1	4.211	0.171	0.965	0.762
	ED2	3.355	0.131		
	ED3	3.763	0.161		
	ED4	5.839	0.234		
	ED5	5.731	0.190		
	ED6	10.154	0.244		
Environmental Performance	EP1	4.416	0.203	0.896	0.644
	EP2	9.304	0.201		
	EP3	8.240	0.221		
	EP4	6.486	0.218		
	EP5	6.291	0.232		
	EP6	7.326	0.165		
Green Capability	GC1	2.756	0.177	0.950	0.737
	GC2	2.234	0.107		
	GC3	3.077	0.169		
	GC4	10.053	0.172		
	GC5	5.053	0.170		
	GC6	9.395	0.171		
	GC7	4.722	0.189		

The Average Variance Extracted (AVE) values for these constructs were all over the suggested 0.50 mark (Hair et al., 2017; 2019). This means each construct explains at least half of the total variation. These results indicate that all reflective constructs showed enough convergent validity (refer to Table 3). Moreover, we utilized the heterotrait–monotrait (HTMT) ratio of correlations method (Hameed et al., 2024; Henseler et al., 2015) to assess discriminant validity. For each construct, both lower-order and higher-order, the HTMT ratios stayed below the limit of 0.90. This shows that constructs are distinct from each other. Thus, we can confidently state that the discriminant validity of the measurement model is well established (Hair et al., 2017; 2019).

Table 3
Discriminant Validity

Constructs	1	2	3	4	5
Corporate Digital Responsibility (1)	-				
Environmental Dynamism (2)	0.833	-			
Environmental Performance (3)	0.747	0.873	-		
Green Capability (4)	0.993	0.759	0.803	-	
Environmental Dynamism X Corporate Digital Responsibility (5)	0.894	0.828	0.826	0.858	-

Structural Model

After validating the measurement model using PLS-SEM, the next step was to evaluate the structural model. Table 4 displays the findings of the direct hypotheses, confirming four direct relationships, with all hypotheses being supported. Notably, CDR has a positive and significant effect on EP (β = .824, p < .05). The relationship between CDR and EP can be exemplified by the direct effect CDR→EP=0.824, highlighting that H1 is supported. When companies apply corporate digital responsibility, it does help improve their environmental performance. The evidence suggests that manufacturing firms can set corporate digital responsibility as a practical goal. By implementing a range of digital technologies like Intelligent production systems, artificial intelligence in production areas, IoT sensors and machine learning firms can have a positive impact on EP. Thus, we propose that a thorough application of CDR through intelligent production systems, artificial intelligence in production areas, IoT sensors and machine learning enables firms to achieve better EP.

CDR is positively and significantly influenced by GC (β = .894, p < .05). Our empirical analysis shows that Hypothesis H2a, which links the CDR to GC, is supported with β = 0.894 (p-value < 0.05), corresponding to a t-value = 8.321. The use of corporate digital responsibility paired with green capability helps firms develop better environmental attitudes. Take intelligent production systems: they assist in planning and optimizing production but face challenges due to waste from packaging handling. However, when they adopt green capabilities, they tackle some inefficiencies and risks linked to logistics effectively. Plus, applying smart sensors for recycling packaging aids this process by providing clear instructions for all stakeholders involved in recycling. Also importantly, different portfolios of digital technologies used in recycling packaging promote responsible digitization and enhance the chances of meeting CDR goals.

GC is positively and significantly affected by EP financial resources (β = .950, p < .05). Our analysis also supports Hypothesis H2b, which connects GC with EP with β = 0.950 and p-value < 0.05; the t-value here is 9.922. Green capability makes a big difference to environmental performance by encouraging organizations to adopt sustainable methods and use resources wisely. When companies manage resources efficiently, they can reduce waste and conserve energy while lowering their overall impact on the environment. Furthermore, green capability pushes innovation that leads to eco-friendly products and processes too (Zhang & Li, 2024). Also noteworthy is how green capabilities help companies stay aligned with environmental regulations while promoting proactive sustainability practices like pollution prevention which relies on advanced monitoring technologies to pinpoint and address potential risks like emissions or waste. Incorporating sustainability deeply into operations means organizations with strong green capabilities can substantially lessen their environmental footprint! This leads to an overall improvement in their environmental performance.

The bootstrapping method was used by including 2000 resampling iterations (Hair et al., 2017) to test the mediation hypotheses. As seen in Table 4 and Figure 2, the mediation analysis results showed strong and positive indirect effects. Notably, CDR had a significant impact on EP (β = .200, p < .05), with GC serving as the mediator. The recognition of green capability as a mediator between CDR and EP indicates that CDR boosts EP by enhancing green capabilities. Organizations that adopt CDR can so effectively develop green capabilities. These capabilities then lead to better environmental outcomes. The link between CDR and EP is direct. However the presence of green practices, innovative technology, and effective resource management within firms, all of which enhance its contribution towards improved EP. This finding emphasizes how CDR allows companies to implement eco-friendly initiatives that greatly improve their environmental performance.

In the context of a one-tailed test at a 5% significance level the path coefficient (β = .001, p = .293) indicates a very weak relationship, yet the interaction effect of ED is significant. This supports the dismissal of Hypothesis 3. Consequently, organizations are unable to leverage the synergies between CDR and environmental dynamism to attain improved levels of EP. As the moderator variable (environmental dynamism) relationship between CDR and EP, is not supported this indicates that environmental dynamism does not play a significant role in influencing the effect of CDR on EP. This suggests that changes in environmental dynamism do not impact the strength or direction of the relationship between CDR and EP.

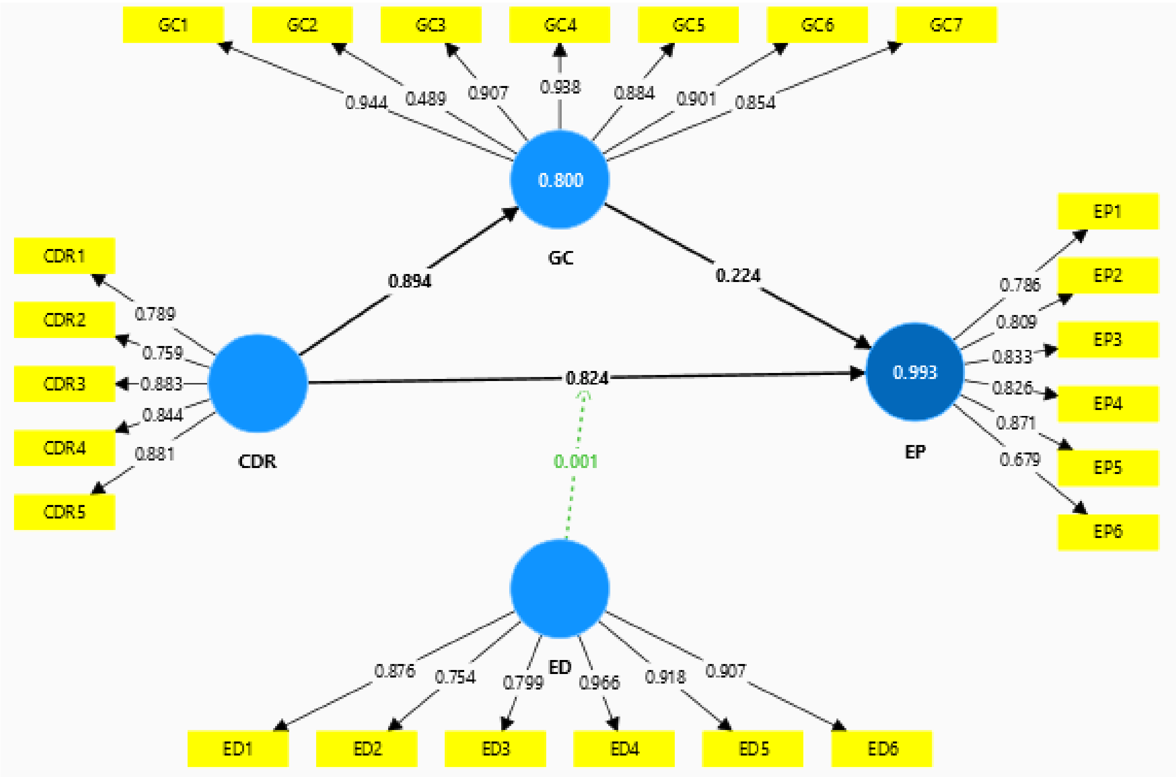

Figure 2: Structural Model

Table 4
Results of Direct and Indirect Effects

Hypotheses		Path Coefficient	Standard Deviation	T-Value	Remarks
		Direct Effects			
Hypothesis 1	CDR→EP	0.824	0.022	8.947	Supported
Hypothesis 2a	CDR→GC	0.894	0.015	8.321	Supported
Hypothesis 2b	GC→EP	0.950	0.023	9.922	Supported
		Indirect Effects			
Mediation	CDR→GC→EP	0.200	0.022	8.947	Supported

Hypothesis 3	ED×CDR→EP	0.001	0.002	0.293	Not Supported

The lack of a noteworthy moderating effect implies that the relationship between CDR and EP remains consistent across different levels of environmental dynamism. Consequently, this may suggest that the advantages derived from implementing CDR initiatives are reliably achieved, regardless of any fluctuations in the external environmental context. To understand the moderation effect, a total effect histogram was created. Figure 3 effectively demonstrates that total effects are small and centred around zero, indicating a weak relationship between ED x CDR and EP. The symmetry suggests an even mix of positive and negative effects, showing inconsistency. This shows hypothesis might not be confirmed. The few extreme effects (outliers) aren't strong enough to change this. Increased ED can diminish the connection between corporate digital responsibilities (CDR) and EP.

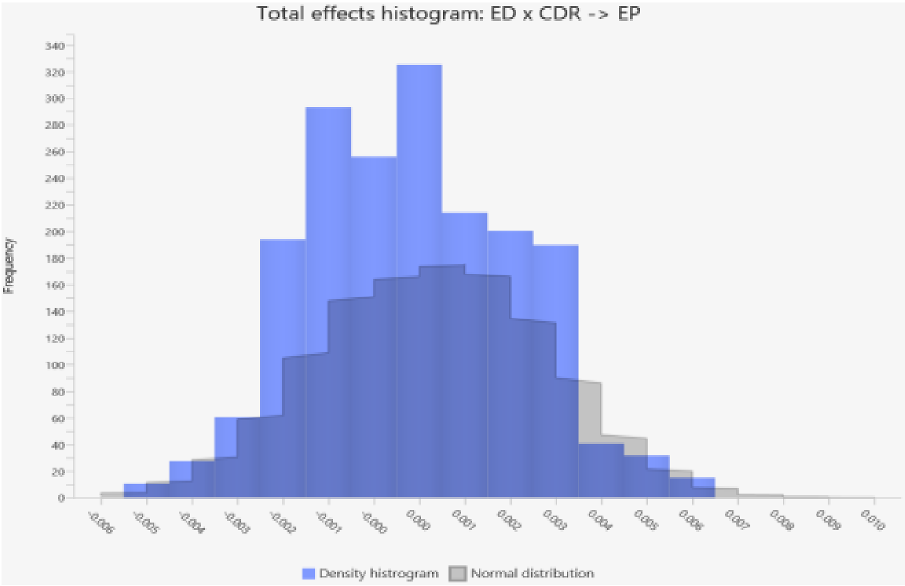

Figure 3: Histogram Chart

Our empirical analysis indicates that Hypothesis H3, which links the CDR to EP, do not reach statistical support. Which shows a coefficient of $\beta = 0.001$ (p-value < 0.05), although significant, shows an insignificant improvement from the original coefficient (the t-test gives a t-value = 0.293). So, introducing ED which includes market dynamism and technological dynamism does not enhance the targeted environmental performance. This could relate to the specific industry chosen for study. For instance, the textile manufacturing sector often does not allow for swift changes in market dynamics. Rapid market shifts aren't common there; similar things apply to technology too. In textiles, tech changes usually don't happen quickly either. But in industries like IT, environmental dynamism could likely boost environmental performance.

Conclusion

Although considerable research has been conducted on environmental performance and CDR, these significant areas have not been extensively studied in conjunction with one another. Drawing inspiration from a distinctive integration of the natural resource-based view of the firm (Hart, 1995) and information processing theory, we introduce a novel perspective that connects digitization with environmental aspects. This connection serves as a pathway through which an organization's strategic green capabilities can be transformed into improved environmental performance. Viewed through the NRBV lens, we posit that green capabilities enable organizations to better navigate sustainability challenges and opportunities while mitigating negative environmental impacts, thereby enhancing the transparency and accountability of their operational practices (Traxler et al., 2020; Wijethilake, 2017).

This hypothesis is evaluated using survey data from 319 manufacturing companies in Pakistan, employing SEM-PLS (SmartPLS 4.0), a method that is characterized by its minimal requirements for normality assumptions and sample size (Tylavsky & Sharp, 1995). The findings support the core assumption of this study and provide detailed insights into how green capabilities influence the relationship between CDR and environmental performance (Shahzad, Qu, Javed, Zafar, & Rehman, 2020). The results from the first hypothesis indicate a positive correlation between CDR and environmental performance. Overall, we conclude that companies dedicated to digitalization and the utilization of digital technologies, with a strong focus on green resources, tend to exhibit superior performance in the industry regarding environmental outcomes. This aligns with the resource-based perspective of natural assets put forward by Hart (1995) and Hart and Dowell (2011), who contend that specific strategies or resources within a company can enhance its environmental performance (Scherer et al., 2018).

More precisely, the findings related to H1 indicate a connection between corporate digital responsibility and environmental performance. This is consistent with earlier studies which recognize CDR, as firms' commitment to ethical, sustainable, and accountable practices, as a crucial factor for achieving sustainability (Massaro et al., 2018) and fostering innovation in environmental practices (Yusoff et al., 2019). This result supports Napoli (2023), which examines the influence of board independence and expenditures on digital technology regarding environmental performance, focusing on Italian firms. Additionally, this outcome aligns with previous research highlighting the significance of CDR in environmental protection and sustainability efforts (Shahzad et al., 2020).

Similarly, it substantiates the findings of Cheng and Zhang (2023), who discuss CDR's role in enhancing environmental sustainability through ethical practices and digital technologies. In contrast to the aforementioned studies, this finding diverges from research such as corporate digital responsibility (Manifesto, 2021), which denies a connection between CDR and environmental performance. Some perspectives propose that the environmental effects of CDR are contingent on the context. For instance, scholars suggest that digitalization mainly affects economic and social dimensions, with ecological effects frequently being indirect or contingent upon other initiatives. Critics argue that CDR emphasizes governance, ethical utilization of technology, and transparency rather than directly targeting improvements in environmental performance.

The findings related to the second hypothesis suggest that green capabilities act as a mediating factor. Prior research conducted by Xu et al. (2024) indicated that a digital sustainability orientation affects environmental outcomes by enabling the reconfiguration of capabilities and aligning digital endeavors with sustainability objectives to enhance performance. Rehman et al. (2022) underscore the significance of green capabilities in improving environmental performance through the reorganization of resources aligned with sustainability goals. Furthermore, the results affirm that green capabilities can enhance the relationship between CDR and environmental performance. This observation aligns with earlier studies indicating that green capabilities are influenced by the environmental strategies and initiatives adopted by a company. This finding emphasizes that organizations focused on green initiatives are more likely to implement environmentally sustainable practices (Zhang & Li, 2024).

Our analysis of the moderation effect (environmental dynamism), which was expected to strengthen the relationship between CDR and environmental performance, did not achieve statistical significance. This indicates that integrating environmental dynamism, encompassing market and technological changes, fails to improve the desired environmental performance outcomes. Nyaberi's (2021) argument that environmental factors such as dynamism, complexity, and munificence do not inherently enhance organizational performance when examined in isolation can be contextualized within the framework of Information Processing Theory. According to IP Theory, organizations must process external information and stimuli effectively to adapt and make informed decisions. The capacity of an organization to effectively process and respond to environmental dynamics is primarily determined by its internal capabilities and structures for information processing (Zioło et al., 2020).

Research by Seo et al. (2020) reveals that when environmental dynamism is not managed properly, it does not directly contribute to improved innovation performance, including environmental results. This perspective closely relates to Information Processing Theory, which asserts that organizations need to interpret and manage external information to adjust to changes in the environment (Daft & Weick, 1984). As environmental dynamism intensifies indicating swift shifts in external elements such as market conditions, technologies, and consumer preferences organizations face an influx of information. In the absence of robust internal mechanisms like knowledge management systems, decision-making frameworks, or adaptable strategies organizations may struggle to process this information effectively. Such difficulties in managing or interpreting a dynamic environment can lead to suboptimal responses, affirming Seo et al. (2020) claim that environmental dynamism does not necessarily result in enhanced innovation or overall performance.

Implications

In this research, we present a theoretical framework for improving understanding of a new concept by integrating CDR and environmental performance. To our knowledge, this is the first study to investigate this subject matter empirically, making a significant contribution to the existing literature (Zioło et al., 2020). We specifically examined the mediating mechanism of green capabilities and the moderating effect of environmental dynamism in the relationship between CDR and EP, using information processing theory and the natural resource-based view as our primary theoretical frameworks.

This study also advances our understanding of the concept of corporate digital responsibility. CDR is a multidimensional construct comprising two primary components: social responsibility and digital technologies (Zhu et al., 2019). Digital technologies like robotic systems, artificial intelligence, digital twin technology, enterprise resource planning (ERP) systems, and machine learning make it easier for companies to meet their environmental goals by letting them be used responsibly. By examining a broader range of digital technologies and their application in a diverse range of environmental practices, this study not only introduces CDR in a meaningful way, but also empirically assesses its impact on environmental performance, providing new insights for both theory and practice (Wang et al., 2022).

Furthermore, our analysis reveals that green capabilities, specifically the development and implementation of sustainable practices, technologies, and processes within organizational production functions, significantly enhance the transition toward improved environmental performance (Wang et al., 2022). By acknowledging the potential risks posed by digital technologies, incorporating green capabilities can facilitate a smoother transition toward environmental sustainability. Thus, manufacturing firms, policymakers, and governments need to recognize digital transformation's challenges and leverage green capabilities to mitigate potential ecological harm (Zhang & Li, 2024).

Furthermore, in the face of increasing environmental dynamism, industrial companies should be proactive in improving their environmental performance rather than only reacting to changes. By anticipating future trends, including new regulations, advancements in technology, and shifts in customer behavior, companies may design long-term sustainability strategies that go beyond compliance (Hamid et al., 2022). Developing an innovative culture is essential to staying adaptable and quickly implementing new technology that can reduce their environmental impact, such as renewable energy sources or energy-efficient machinery. Matching CEO and employee incentives with sustainability goals are also essential to ensuring that everyone in the organization is motivated to contribute to environmental reforms. Neverthless, sustainability requires collaboration across the whole value chain (Zhang & Li, 2024).

Limitations and Future Research

Our study has several limitations that also present opportunities for future research within the same domain. First, conducting this research in a single country necessitates additional studies to generalize the findings to other developing nations and compare them with those from developed countries. Second, our study assessed only a few CDR antecedents and outcomes in terms of their impacts, and future researchers should delve into the literature to identify support from other theoretical frameworks. Moreover, our investigation concentrated on a limited number of components of CDR, whereas the field offers a rich array of opportunities for exploration. Future studies could develop alternative mediators and moderators to examine their influence on achieving enhanced environmental performance.

For future investigations, we recommend employing a mixed-methods approach that includes in-depth qualitative research alongside sophisticated quantitative analyses. Consequently, organizations are unable to leverage the synergies between CDR and environmental dynamism to attain improved levels of EP. For practitioners, this finding highlights the importance of prioritizing corporate digital responsibility initiatives to improve environmental performance without heavily factoring in the level of environmental dynamism within their strategic plans. Future studies could examine other variables that might moderate the relationship between CDR and EP, or assess different contexts or sectors to see if the lack of a moderating effect is consistent in other settings (Wang et al., 2022).

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