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## Article

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## Article

# Green Intellectual Capital and Corporate Environmental Performance: Does Environmental Management Accounting Matter?

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**Abstract:** This study investigates the relationship between green intellectual capital and corporate environmental performance, with a specific focus on the moderating role of environmental management accounting. Data were collected from a sample of 298 employees working in the Egyptian industrial sector and analyzed using smart partial least squares (SmartPLS) software. The empirical results revealed a statistically positive and significant impact of all green intellectual capital components on corporate environmental performance, indicating that green intellectual capital is a critical determinant in enhancing environmental performance. Further, the analysis reveals that environmental management accounting functions as a significant moderator in the relationship between green intellectual capital and corporate environmental performance. The model explains 80.2% of the variance in corporate environmental performance, providing strong empirical support for this study's hypotheses. These findings have important practical implications for companies working in the Egyptian context. They can help in guiding the development of corporate policies and strategies that improve environmental performance. This research also makes a significant contribution to the literature by being one of the first to study the moderating role of environmental management accounting practices in an emerging market like Egypt, as most early studies have concentrated on the direct relationship between green intellectual capital, environmental management accounting, and corporate environmental performance. This helps in better understanding of these concepts and how they interact.

**Keywords:** green intellectual capital; corporate environmental performance; environmental management accounting; sustainability; emerging economy; Egypt



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## 1. Introduction

The impact of corporate activities on the environment has become a major global concern. This is largely because companies are using more resources and conducting more industrial activities to expand their business and increase their profit regardless of the impact of their activities on the environment (Yu et al. 2020). Industrial activities have caused considerable damage to the environment, including air and water pollution and rising temperatures (Singh et al. 2020). This irresponsible behavior has pushed stakeholders to pressure companies to reduce waste and be more environmentally responsible. As a result, manufacturing companies are now focusing more on being environmentally friendly to avoid losing customers and market share (Hanif et al. 2023; Gunarathne et al. 2021).

Recent academic endeavors have concentrated on both environmental management accounting (EMA) and Corporate Social Responsibility (CSR), especially within organizations that extensively disclose high spending on CSR activities. This body of literature seeks to critically assess how well these organizations meet their commitments to transparency, covering both financial and non-financial aspects (Metwally et al. 2022). In less

developed countries (LDCs), scholars have explored the relationship between CSR practices and corporate environmental performance (CEP), noting their significance in legitimizing corporate actions (Alnaim and Metwally 2024; Buhaya and Metwally 2024), impacting earnings management (Abdelfattah and Elfeky 2021), and influencing financial performance (Sial et al. 2018). Furthermore, CSR has been linked to enhancing employee creativity (Abdelmotaleb et al. 2018), responding to social and political dynamics that drive changes in CSR practices (Diab and Metwally 2020), and acting as a rhetorical device to disguise cost-saving measures (Metwally et al. 2022).

EMA proves to be effective in enhancing CEP, overcoming the limitations of conventional accounting practices that concentrates only on financial information and its disclosure (Ismail et al. 2014). EMA aids organizations in efficiently attaining environmental, economic, and financial objectives. By incorporating environmentally friendly practices and waste reduction procedures, organizations using EMA project a positive image to stakeholders and attract investors (Latan et al. 2018).

EMA aligns with green initiatives, fostering environmental performance and securing a robust competitive stance in the market. The management accounting literature recently has an increasing number of studies that concentrate on the impact of EMA on CEP (Christ and Burritt 2013; Phan et al. 2017; Asiaei et al. 2022a, 2022b; Hanif et al. 2023). However, the efficacy of concurrently applying these practices to significantly enhance a company's overall environmental performance remains uncertain. Notably, in certain regions, environmental performance reporting remains voluntary, and transparency is often compromised due to limited disclosures, particularly in developing nations (Metwally et al. 2021; Metwally 2022; Ali et al. 2024). This lack of transparency highlights the urgent need for further investigation (Asiaei et al. 2022a, 2022b). Along with the increased concentration on EMA, many studies have recently concentrated on green intellectual capital (GIC) and its impact on environmental performance and green supply chains (Buhaya and Metwally 2024). Traditionally viewed as a primary source of economic value, intellectual capital is now recognized as a crucial component in addressing the ecological challenges confronting modern societies (Massaro et al. 2018).

GIC is conceptualized as the amalgamation of existing skills and knowledge deployed within an organization for both organizational and environmental activities and processes, thereby bestowing a competitive advantage (Yusliza et al. 2020). Rooted in knowledge-based theory, it is posited that GIC plays a pivotal role in promoting knowledge sharing and experiences among individuals within the organization. This, in turn, is expected to facilitate the exchange of knowledge regarding the environmental aspects and skills necessary for achieving sustainable performance outcomes (Yusliza et al. 2020). Consequently, the strategic utilization of intellectual capital geared towards environmental initiatives by firms serves to enhance CEP (Buhaya and Metwally 2024).

From a theoretical perspective, knowledge-based theory was deployed to explain that GIC is instrumental in fostering knowledge sharing and the exchange of experiences among organizational members. This knowledge exchange is expected to advance understanding of environmental issues and the skills needed to achieve sustainable performance outcomes (Asiaei et al. 2022a, 2022b). As a result, the strategic use of intellectual capital focused on environmental initiatives enables firms to improve their CEP (Mansoor et al. 2021; Shah et al. 2021; Asiaei et al. 2022a, 2022b; Asiaei et al. 2023).

The management accounting (MA) literature increasingly acknowledges the critical integration of corporate strategic plans, with a particular focus on management prioritization of sustainability and its related activities (Asiaei et al. 2021; Arjaliès and Mundy 2013). This research stream employs the resource-based view (RBV) theory to elucidate how organizations seek to establish a sustainable competitive advantage through the strategic deployment of diverse resources. The deliberate integration of these resources with various operational activities is posited to enhance value creation not only for products but for services (Nagano 2020). Within the RBV framework, scholars argue that organizations driven by an awareness of external environmental factors can optimize the utilization of

natural resources while concurrently minimizing waste generation (Hart 1995; Hart and Dowell 2011). Such a strategic orientation is proposed to propel organizations toward achieving a competitive advantage (Al-Khatib and Shuhaiber 2022).

An alternative theoretical framework is the intellectual capital-based view (ICBV) theory, which extends the resource-based view (RBV) theory by integrating knowledge management practices (Jardon and Martínez-Cobas 2019). The ICBV addresses a notable limitation in the RBV, specifically its inadequate methods for measuring intangible assets (Buhaya and Metwally 2024). By conceptualizing intellectual capital through elements such as patents and tacit knowledge, the ICBV provides a more precise framework for analysis and empirical testing. This study adopts the ICBV perspective, defining intellectual capital as the unique knowledge assets that confer a competitive advantage to a firm. These assets include the specialized knowledge embedded within the firm's human capital (employee skills and expertise), structural capital (organizational processes and routines), and relational capital (external partnerships) (Buhaya and Metwally 2024).

It is now apparent that there is a clear research gap in the existing literature, as there is a scarcity of studies that concentrate on the moderating role of EMA in the relationship between GIC and CEP. Furthermore, the combined effects of GIC components and EMA in enhancing CEP are under-explored, with the notable exception of Asiaei et al. (2022a) who found that GIC and EMA independently impact CEP positively, and that EMA mediates the relationship between GIC and CEP in the Iranian context. The current study aims to fill part of this gap and extend the debate in the literature surrounding the role EMA plays in the relationship between GIC and CEP. One of the main contributions of the current research is the concentration on the Egyptian industrial sector. The Egyptian context is worthy of study as there have been many recent reforms in the CSR regulations, economic restriction and, finally, a recovering economy after two revolutions. These unique characteristics have had an impact on individual and corporate behavior and strategies (Metwally et al. 2022; Ali et al. 2024; Metwally and Diab 2021). The current study seeks to answer two central questions: (1) How does GIC impact CEP? (2) Does EMA moderate the relationship between GIC and CEP?

The current study introduces a novel theoretical construct that significantly extends the existing body of literature pertaining to environmental performance. This study's primary contribution lies in its comprehensive examination of the interrelationships between GIC and CEP, with a particular emphasis on the moderating role of EMA. The relevance of this research is heightened by its focus on validating the proposed framework within a critical industrial sector in the emerging economy of Egypt. This paper is structured as follows: Section 2 provides a theoretical foundation for this study by formulating hypotheses regarding the influence of GIC subcomponents (green human capital, green structural capital, and green relational capital) on CEP. Additionally, this section elaborates on the underlying theoretical framework guiding the research. Section 3 outlines the methodological approach adopted for data collection and analysis. Section 4 presents the empirical findings, including a detailed discussion of the statistical results. Section 5 offers a comprehensive interpretation of the findings, drawing conclusions and addressing the implications of the research. Finally, Section 6 highlights this study's limitations, potential future research directions, and the broader implications of the findings for both academic and managerial practice.

## 2. Theoretical Framework and Hypotheses Development

### 2.1. Green Intellectual Capital and CEP

#### 2.1.1. Green Human Capital and CEP

Green human capital (GHC) represents a critical intangible asset intrinsically linked to an organization's employees. As explained by Wright et al. (1994), GHC forms the cornerstone of sustainable competitive advantage, emanating from a skilled and talented workforce rather than readily accessible or duplicable tangible resources. In the context of increasingly dynamic industries, the necessity for fundamental strategic resources that

foster competitive superiority becomes evident, with GHC fulfilling this role by enhancing both competitive positioning and overall environmental performance (Asiaei et al. 2022a, 2022b). Moreover, the continual acquisition and development of new skills by employees serve to elevate their human capital, thereby improving efficiency and organizational outcomes (Allameh 2018; Massaro et al. 2018).

Hence, the efficiency of workers significantly contributes to enhanced overall performance, including environmental performance and sustainability (Asiaei et al. 2022b; Buhaya and Metwally 2024; Hameed et al. 2023; Hanif et al. 2023; Bivona and Scirè 2024; Martínez-Falcó et al. 2024). Many recent studies connected GHC to enhanced environmental performance, particularly in firms which are environmentally responsible (Mansoor et al. 2021; Hameed et al. 2023; Hanif et al. 2023; Bivona and Scirè 2024; Martínez-Falcó et al. 2024). Prior research in the literature clarified that GHC fosters a positive synergy between environmental ethics and green innovation performance (Sheikh 2022). According to Huang and Kung (2011), GHC is essential for ensuring compliance with environmental standards and adding value to the organization. Further, Mansoor et al. (2021) added that GHC helps companies to effectively manage their green agendas, leading to improved environmental performance. Similarly, Asiaei et al. (2022a) emphasized that the knowledge, skills, competencies, attitudes, and innovative capacities of the workforce regarding environmental conservation are vital for advancing CEP.

GHC alone is unlikely to achieve the desired outcomes without the complementary support of an appropriate organizational structure, information systems, and strategic frameworks (Jardon and Dasilva 2017). In this context, well-developed green structural capital plays a crucial role through promoting an environment that motivates organizational members to engage in environmental protection initiatives, ultimately enhancing environmental performance (Mansoor et al. 2021; Asiaei et al. 2022a, 2022b; Asiaei et al. 2023; Buhaya and Metwally 2024).

Extensive research has revealed a significant relationship between GHC and the efficiency of green supply chain operations (Chen 2008; Maaz et al. 2022; Buhaya and Metwally 2024), along with corresponding advancements in sustainable performance indicators (Jirakraisiri et al. 2021). In its conventional definition, human capital comprehends the collective skills, knowledge, expertise, and capabilities that individuals within an organization possess. This concept integrates these skills, such as education, training, experience, and innate talents, which together enhances the ability of individuals to execute tasks, address complex challenges, and foster innovation within the organizational framework (Kramer and Kroon 2020).

Viewed through the natural resource-based view (NRBV) lens, GHC represents the collective environmental knowledge, skills, capabilities, and experiences of employees, which are essential for environmental protection and awareness of ecological risks (Shoaib et al. 2021). Although human capital is inherently challenging to sustain due to its intangible nature and the complexities of embedding environmental concepts in employees' minds, it plays a crucial role in providing firms with a unique competitive edge. This advantage is driven by the capacity of human capital to generate innovative ideas and drive organizational change (Buhaya and Metwally 2024). Thus, intellectual capital is increasingly seen as a key determinant of organizational success and a vital element in enhancing overall performance (Kryscynski et al. 2021).

Many studies in the literature have elucidated the pivotal role of GHC as a significant determinant of enhanced CEP (Mansoor et al. 2021; Asiaei et al. 2022a, 2022b; Asiaei et al. 2023; Buhaya and Metwally 2024). The acquisition of essential knowledge and skills through GHC enables organizations to effectively address environmental challenges (Jirakraisiri et al. 2021), thereby improving process efficiency (Sheikh 2022). Moreover, GHC serves as a catalyst for the creation of innovative environmental solutions, contributing to the advancement of CEP through the introduction of novel practices (Song et al. 2021). Furthermore, the existing literature indicates that GHC exhibits a pronounced responsiveness to environmental training and learning initiatives, which enhances green supply



chain performance (Buhaya and Metwally 2024). Based on these findings, the following hypothesis is proposed:

**H1.** *GHC positively impacts CEP.*

### 2.1.2. Green Structural Capital and CEP

Structural capital encompasses the organizational capabilities embedded within firms that enable the conversion of ideas and innovations produced by employees into tangible, actionable assets that can be leveraged within the organizational context (Barão and da Silva 2014). It can be viewed as the aggregate of knowledge acquired through routine operations, knowledge dissemination among employees, and interactions with external stakeholder (Barbery and Torres 2019). Structural capital typically includes a variety of elements, such as policies, procedures, patents, and knowledge repositories (Asiaei et al. 2018). It works in conjunction with human capital to provide solutions to organizational challenges (Alkhatib and Valeri 2024; Ullah et al. 2022).

Green structural capital (GSC) refers to the array of organizational assets and capabilities dedicated to environmental sustainability, including systems, protocols, databases, and patents that are integral to implementing green initiatives. These resources are managed and utilized by the organization to support environmental preservation efforts (Benevene et al. 2021; Chen 2008). GSC plays a crucial role in enabling environmental protection programs by providing the necessary infrastructure and support (Yusoff et al. 2019). Furthermore, GSC contributes to transforming organizational culture towards greater environmental awareness and responsibility (Buhaya and Metwally 2024). It also assists in guiding employees towards effective environmental practices, supporting and steering environmental programs within the organizational structure (Benevene et al. 2021; Hameed et al. 2023; Hanif et al. 2023; Bivona and Scirè 2024; Martínez-Falcó et al. 2024).

The extent to which companies commit to CSR and focus on environmental issues significantly elevates the importance of GSC (Maaz et al. 2022). When senior management emphasizes a green agenda, organizations are more likely to integrate employee expertise and knowledge into their internal systems, thereby developing GHC (Secundo et al. 2020). Early studies in the literature demonstrated that GSC positively impacts both performance enhancement and sustainability, while simultaneously generating competitive advantages (Al-Khatib and Shuhaiber 2022; Buhaya and Metwally 2024). GSC is recognized in the literature as a crucial factor in improving CEP (Asiaei et al. 2022a, 2022b; Asiaei et al. 2023). It achieves this by facilitating knowledge exchange among stakeholders committed to successful environmental strategies (Ullah et al. 2022). Additionally, GSC enables organizations to effectively utilize their core capabilities to meet their environmental objectives, leading to sustainable development and enhanced environmental protection (Yusliza et al. 2020; Khan et al. 2021).

Although the importance of structural capital in achieving sustainable development and improving overall performance is well-recognized, the existing research highlights that GSC plays a significant role in enhancing CEP. This enhancement is achieved through the effective integration of organizational knowledge and technological capabilities, leading to improved performance results (Mubarik et al. 2022). To further boost CEP, it is essential to strategically foster and strengthen key relationships with primary stakeholders, such as customers and suppliers (Buhaya and Metwally 2024; Asiaei et al. 2022a, 2022b). Based on this, the following hypothesis is formulated:

**H2.** *GSC positively impacts CEP.*

### 2.1.3. Green Relational Capital and CEP

Green relational capital (GRC) represents the network of connections an organization maintains with its stakeholders, including customers, suppliers, retailers, and government entities. To sustain competitiveness in the industry, companies must align their goals with

those of key stakeholders. The interaction between firms and their stakeholders is based on a reciprocal relationship, where trust is a crucial component (Morgan and Hunt 1994). Strong, trust-based relationships tend to be more enduring and foster continuous learning. Bonner and Walker (2004) have suggested that such close ties enable organizations to achieve superior performance (Mansoor et al. 2021).

In the manufacturing industry, many organizations cultivate strong connections with their stakeholders, such as suppliers and retailers, to stay attuned to emerging business trends and practices (Longoni and Cagliano 2018). A close partnership with suppliers can provide companies with timely access to raw materials, often at lower costs and with favorable payment terms. Additionally, these relationships can offer insights into advanced manufacturing techniques and expertise. Retailers, on the other hand, play a crucial role in conveying the latest consumer demands and preferences, as well as reporting any product defects highlighted by customers (Mansoor et al. 2021). The intelligence gathered from these stakeholders enables organizations to respond swiftly and improve their overall performance (Walter 2003). Consequently, a strong relationship with stakeholders fosters sustainable competitive advantages by developing GRC (Yusliza et al. 2020). Moreover, collaboration with competitors can also be beneficial in pursuing environmental management systems (Kuo et al. 2015).

Companies can create value and achieve competitive advantages by effectively utilizing their network of relationships (Al-Khatib 2022). Relational capital refers to a company's ability to interact productively with key stakeholders within its environment (Barbery and Torres 2019). This form of capital embodies the value derived from both internal and external partnerships (Buhaya and Metwally 2024). Relational capital is crucial for gaining access to scarce resources, obtaining hard-to-access information, and acquiring specialized knowledge through collaborative interactions with relevant stakeholders (Xu et al. 2019). These collaborative efforts enhance a firm's ability to deliver value to customers by fostering the development of innovative and competitive products (Alves et al. 2021).

GRC refers to a firm's connections with key stakeholders concerning environmental issues and sustainability efforts. These relationships play a crucial role in establishing a competitive edge (Atiku 2019). GRC acts as a vital channel for communicating a company's CSR initiatives and strategies (Chen and Chang 2013), which helps build trust between the organization and its stakeholders (Al-Khatib 2022). Moreover, GRC enhances a firm's capacity for learning and training, as well as its access to valuable knowledge resources (Benevene et al. 2021). This improvement in capabilities fosters internal knowledge growth, ultimately driving the development of new green innovations (Rehman et al. 2021).

Recently, many studies have tried to establish a link between GRC and CEP. Huang and Kung (2011) identified a positive indirect relationship between GRC and competitive advantage. In a similar vein, Delgado-Verde et al. (2014) suggested that GRC fosters worker cooperation, leading to successful product innovation within organizations. A more recent study, by Yusoff et al. (2019), confirmed a positive correlation between GRC and business sustainability. Furthermore, Shah et al. (2021) and Mansoor et al. (2021) observed that environmentally conscious firms are likely developing a stable pro-environmental structure and organizational capabilities to address climate challenges. GRC is crucial for fostering collaborative relationships with external entities that advocate for environmental protection (Chuang and Huang 2018). Shah et al. (2021) also noted that green relationships among partners are increasingly recognized as key determinants of both environmental responsibility and pro-environmental performance within organizations. Recent studies by Asiaei et al. (2022a, 2022b) and Asiaei et al. (2023) confirmed these earlier findings, demonstrating a positive and significant impact of GRC on CEP. Finally, Buhaya and Metwally (2024) found that GRC positively influenced green initiatives in Egyptian supply chain management, thereby enhancing overall supply chain performance. Based on these findings, the following hypothesis is proposed:

**H3.** *GRC positively impacts CEP.*

## 2.2. EMA Moderating Role: The Impact of Environmental Management Accounting

EMA is founded on the principle that the environmental management practices of corporations can be effectively facilitated through the utilization of accounting information. This information serves diverse objectives, such as strategic planning, decision-making processes, and operational control (Burritt et al. 2019; Asiaei et al. 2022a). Despite the absence of a unified identity stemming from its dynamic evolution, EMA fulfills the critical role of systematically gathering, analyzing, and disseminating information pertaining to corporate sustainability. The aim is to empower managers in achieving the goals and objectives relating to sustainability and environmental care (Gunarathne et al. 2021).

In a more specific context, EMA is conceptualized as an accounting framework applicable to diverse organizational decision-making scenarios involving activities that relates to the environment and its management activities (Gunarathne et al. 2021). Within this framework, decision support encompasses functions such as compliance monitoring, financial disclosure and reporting, decision-making process, and fostering continuous improvements (Pasetti et al. 2014). EMA plays a crucial role in supporting the implementation of environmental strategies through enhancing both financial and non-financial environmental information (Burritt et al. 2002). Consequently, EMA represent a comprehensive set of principles and methodologies that supply information essential for the effective implementation and management of environmental strategies (Burritt et al. 2019; Gunarathne et al. 2021).

Nevertheless, EMA involves the integration of both financial and non-financial information by organizations to evaluate the implications of decisions aimed at enhancing CEP (Asiaei et al. 2022a). Numerous studies have underscored the pivotal role of EMA in achieving environmental sustainability, asserting that proficient implementation of EMA can confer a competitive advantage on organizations by augmenting their CEP (Visintin et al. 2022). Through effective EMA implementation, organizations can contribute significantly to CEP, simultaneously yielding financial, economic, and environmental benefits (Burritt and Christ 2016). The disclosure of environmental concerns in financial statements to address environmental-related issues is posited as a means for firms to enhance financial and economic outcomes (Ogunode 2022). The reluctance of certain organizations to prioritize environmental considerations in accounting practices, owing to conventional norms, is cautioned against due to the potential negative impact on stakeholders (Agustia et al. 2019). Organizations emphasizing profit maximization at the expense of environmentally friendly strategies may face substantial financial losses in the future, given the contemporary emphasis on environmental stability. Stakeholder pressure is compelling organizations to enhance their CEP, prompting proactive initiatives in environmental stability. EMA emerges as a valuable strategy for formulating and executing environmental strategies by collating both financial and non-financial information relating to environmental activities (Sari et al. 2021). Obtaining accurate, relevant, and timely environmental information becomes imperative for organizations seeking to implement a successful environmental strategy (Hanif et al. 2023). Based on this, the following hypotheses are proposed:

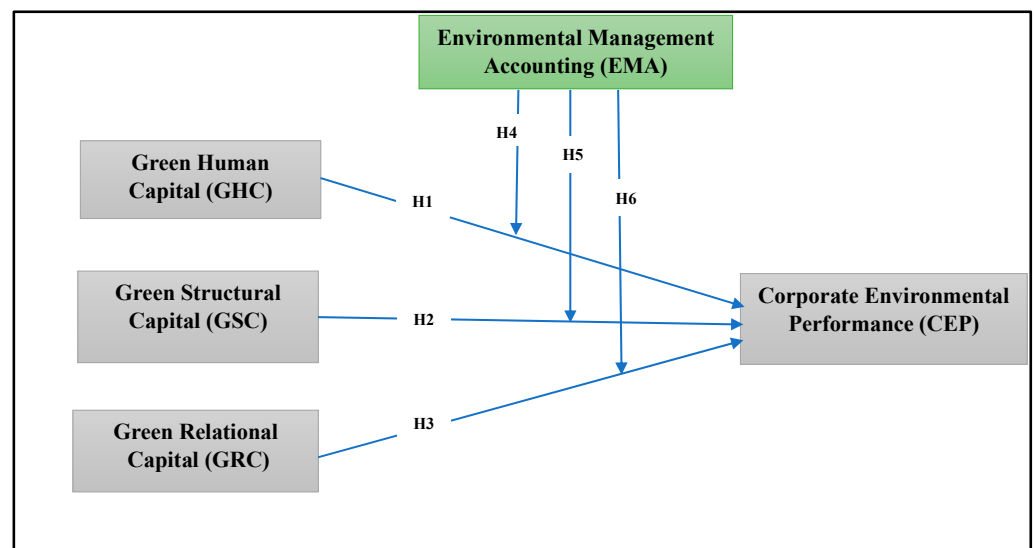
**H4.** *EMA moderates the relationship between GHC and CEP.*

**H5.** *EMA moderates the relationship between GSC and CEP.*

**H6.** *EMA moderates the relationship between GRC and CEP.*

The relationship between the study variables is presented in Figure 1 below.





**Figure 1.** Study framework model.

### 3. Research Methodology

#### 3.1. Data Collection and Survey Design

The sample data for this study were gathered via a questionnaire, wherein the sample for this study consisted of manufacturing companies listed on the Egyptian Stock Exchange (ESE). The manufacturing industry was selected because of its substantial environmental effect and the environmental issues that these businesses frequently face. This emphasizes how important EMA adoption is for Egyptian industrial enterprises. The ESE was the source of the manufacturing companies' list. According to [Asiaei et al. \(2022b\)](#), [Alnaim and Metwally \(2024\)](#), and [Lin et al. \(2024\)](#), managers in these manufacturing organizations were sent a total of 500 questionnaires due to their competence in both accounting and a strategic view on the application of EMA and GIC. Both manual and web-based methods were used to conduct the survey. A 5-point Likert scale was used in the poll to allow respondents to indicate how much they agreed or disagreed, ranging from 1 (totally disagree) to 5 (absolutely agree). To measure the participants' answers to the questionnaire items, this scale was used. Data collecting for this study began in January 2024 and continued for four months. Of the 500 questionnaires sent, 298 were returned, resulting in a response rate of 59.6%. Table 1 presents a demographic breakdown of the respondents.

**Table 1.** Demographic information (n = 298).

		Freq.	%
Gender	Female	88	70.5
	Male	210	29.5
Experience (years)	1–5 years	9	3
	6–10 years	73	24.5
	11–15 years	96	32.2
	More than 15 years	120	40.3
Educational Level	Bachelor	110	37
	Masters	155	52
	PhD	33	11

Table 1. Cont.

		Freq.	%
Industry Type	Textile and Durables	31	10.4
	Food, Beverages, and Tobacco	53	17.8
	Healthcare and Pharmaceuticals	55	18.4
	Basic Resources	52	17.5
	Building Materials	62	20.8
	Industrial Goods, Services and Automobiles	45	15.1
Total		298	100

### 3.2. Measures and Scale Development

The three separate sections of the survey that were used in this study were carefully designed to satisfy the unique requirements of the investigation. Originally designed on the basis of knowledge from previous research, the tool was refined to fit the specific setting of the current study. The first section dealt with obtaining the study participants' express informed consent, in which they stated clearly that they would like to participate in the research. Then the gathering of the respondents' demographic data came next. Then, the second section included GIC-related questions divided into GHC, GSC, and GRC categories, based on research by [Chen \(2008\)](#), [Asiaei et al. \(2022b\)](#), and [Buhaya and Metwally \(2024\)](#). The instrument's third section consisted of questions about CEP and EMA. The six CEP questions were taken from research works by [Asiaei et al. \(2022b\)](#), [Hanif et al. \(2023\)](#), [Hameed et al. \(2023\)](#), and [Lin et al. \(2024\)](#). The EMA scale was evaluated using a tool that was supplied by [Alnaim and Metwally \(2024\)](#), [Latif et al. \(2020\)](#), [Christ and Burritt \(2013\)](#), and [Phan et al. \(2017\)](#). In Table 2, we list every item on the scale in detail.

Table 2. Measurement Model.

Scale Variables and Items	Outer Loading	Alpha	CR	AVE
<b>Green Human Capital (GHC)</b>		0.880	0.912	0.676
The firm's employees are highly skilled in both practical and scientific aspects of environmental preservation.	0.822			
The company offers continuous training to its staff in order to enhance their environmental knowledge and skill sets.	0.826			
The company's staff members perform well when providing environmental services.	0.862			
While performing environmental tasks and activities inside the company, the workforce cooperates as a cohesive team.	0.858			
Our employees are more environmentally consciousness compared to competitors from other organizations	0.736			
<b>Green Structural Capital (GSC)</b>		0.816	0.861	0.554
Our company uses a sophisticated management system for environmental protection	0.714			
Our company consistently makes investments in eco-friendly facilities.	0.840			
Our company implements efficient procedures that save resources and help to preserve the environment.	0.929			
Knowledge management systems are employed by our firm to enable staff members to share their environmental knowledge.	0.891			

Table 2. Cont.

Scale Variables and Items	Outer Loading	Alpha	CR	AVE
Databases are used by our company to record of employees' environmental expertise and knowledge	0.855			
To store knowledge, our company maintains records of software and patents pertaining to environmental intellectual property rights.	0.834			
<b>Green Relational Capital (GRC)</b>		0.919	0.938	0.717
Our firm takes its clients' environmental concerns into account when providing services.	0.736			
When a company offers eco-friendly products, customers are satisfied.	0.745			
Our firm maintains enduring, ecologically conscious cooperative relationships with its suppliers.	0.724			
With customers and guests alike, our firm fosters long-lasting, environmentally oriented collaborative relationships.	0.724			
In order to promote the creation of new environmental technologies and enhance environmentally friendly practices, our company actively collaborates with external entities.	0.791			
<b>Environmental Management Accounting (EMA)</b>		0.816	0.867	0.565
All physical inputs and outputs, including materials, energy, water, wastes, and emissions, are meticulously recorded and captured by our company's accounting system.	0.754			
Our company's accounting system can perform analysis of product inventories, evaluations of product improvements, and assessments of the environmental effects of products.	0.769			
Our company's accounting system can identify, classify, and estimate expenses and liabilities related to the environment.	0.749			
Our company's accounting system includes the capacity to create and use environment-related cost accounts.	0.751			
Our company's accounting system can assign costs associated with the environment to products.	0.737			
<b>Corporate Environmental Performance (CEP)</b>		0.893	0.919	0.654
Our firm has cut back on air emissions and waste.	0.838			
Our firm has reduced its energy and water consumption.	0.909			
The amount of non-renewable materials, chemicals, and components that our company purchases have decreased.	0.829			
The incidence of environmental incidents at our firm has dropped.	0.740			
By adhering to environmental regulations, our company has enhanced its environmental status.	0.714			
Our firm offers environmental education to both the public and its staff.	0.808			

### 3.3. Data Analysis Methods

The SmartPLS-4 program was chosen by the researchers as the main data analysis tool for this investigation due to its exceptional capability in managing intricate structural equation modeling (SEM). Exploratory research benefits greatly from the software's versatility and intuitive interface. According to [Hair et al. \(2019\)](#), SmartPLS is unique in that it can handle non-normal data distributions and analyze lower sample sets. Partial least squares structural equation modeling (PLS-SEM) was found to be the most effective approach due to the complexity of the models, which included various independent and dependent variables that required causal analysis. PLS-SEM is also a good choice for research involving complex theoretical frameworks and examining the correlations between

latent variables (Hair et al. 2021). The measurement model's reliability and validity must be checked carefully when using PLS-SEM, followed by a detailed investigation of the structural model's correlations and hypotheses.

### 3.4. Common Method Bias (CMB)

Common method bias (CMB), which can lead to inaccurate correlations between variables, must be taken into consideration in survey-based research. According to George and Pandey (2017), CMB happens when the measuring techniques have a greater impact on the findings than the underlying structures under investigation. To address this possible problem, a number of actions were taken throughout this investigation (Viswanathan and Kayande 2012). We have crafted the questionnaire using clear and concise wording to lessen the possibility of misunderstandings and misinterpretations. This made sure that the questions were accurately understood by the replies. Second, we helped to increase the response rate by assuring respondents that their information would be kept private.

To assess the existence of CMB, we employed Herman's single factor approach, which was put out by Podsakoff and Organ (1986). A single component was only able to account for 42.22 percent of the total variation, which is less than the 50% requirement. This suggests that there aren't any notable occurrences of CMB in the data. These steps were performed to make sure that our study findings are accurate and that any associations between variables we found are real and unaffected by errors in methodology.

## 4. Results

### 4.1. Measurement Model Assessment

We employed the convergent and discriminant validity techniques to assess the validity and reliability of our data and evaluate the measurement model. When the selected indicators indicate a theoretical relationship with the constructs they represent convergent validity is established. Table 2 indicates that the outer loadings of all indicators exceeded the 0.70 threshold, which confirms their relevance. We also considered Cronbach's alpha, average variance extracted (AVE), and composite reliability (CR) when evaluating the convergent validity (Hair et al. 2021). Cronbach's alpha and CR values of all constructs were above 0.70 and AVE values were above 0.50, which meet the criteria established by (Hair et al. 2021). Interestingly, the measurement scale items' variance inflation factor (VIF) values were consistently less than 5, which suggests that multicollinearity problems are not present.

Both the Fornell–Larcker and heterotrait–monotrait (HTMT) ratios were utilized for discriminant validity, since they are often used and well accepted criteria in social science research. The Fornell–Larcker criterion was further satisfied because all constructions' diagonal values are more significant than the predetermined threshold (below 0.90) (Henseler et al. 2015). The values of each construct are less than 0.90, as Table 3 demonstrates. The results in Table 4 show that outer-loadings for all latent variables significantly outweighed cross-loadings, suggesting considerable convergent validity.

**Table 3.** Scales Discriminant Validity Measures of Scales.

	Fornell-Larcker					HTMT				
	CEP	EMA	GHC	GRC	GSC	CEP	EMA	GHC	GRC	GSC
<b>1. CEP</b>	<b>0.830</b>									
<b>2. EMA</b>	0.638	<b>0.752</b>				0.708				
<b>3. GHC</b>	0.809	0.598	<b>0.822</b>			0.821	0.660			
<b>4. GRC</b>	0.687	0.729	0.664	<b>0.846</b>		0.716	0.547	0.697		
<b>5. GSC</b>	0.723	0.709	0.680	0.633	<b>0.744</b>	0.800	0.794	0.752	0.666	

**Table 4.** Cross-loadings Indicators.

	CEP	GHC	GRC	GSC	EMA
CEP-1	<b>0.838</b>	0.570	0.533	0.608	0.453
CEP-2	<b>0.909</b>	0.586	0.629	0.616	0.577
CEP-3	<b>0.829</b>	0.542	0.618	0.556	0.574
CEP-4	<b>0.740</b>	0.541	0.528	0.528	0.460
CEP-5	<b>0.714</b>	0.534	0.480	0.573	0.521
CEP-6	<b>0.808</b>	0.604	0.525	0.606	0.518
GHC-1	0.629	<b>0.822</b>	0.580	0.556	0.466
GHC-2	0.625	<b>0.826</b>	0.518	0.487	0.411
GHC-3	0.550	<b>0.862</b>	0.568	0.594	0.589
GHC-4	0.566	<b>0.858</b>	0.483	0.603	0.509
GHC-5	0.617	<b>0.736</b>	0.597	0.512	0.469
GRC-1	0.329	0.284	<b>0.736</b>	0.383	0.583
GRC-2	0.361	0.312	<b>0.745</b>	0.378	0.509
GRC-3	0.383	0.377	<b>0.724</b>	0.330	0.535
GRC-4	0.500	0.532	<b>0.724</b>	0.432	0.469
GRC-5	0.550	0.521	<b>0.791</b>	0.565	0.612
GSC-1	0.604	0.509	0.508	<b>0.714</b>	0.491
GSC-2	0.606	0.604	0.543	<b>0.840</b>	0.607
GSC-3	0.533	0.620	0.592	<b>0.929</b>	0.618
GSC-4	0.538	0.608	0.537	<b>0.891</b>	0.524
GSC-5	0.553	0.540	0.496	<b>0.855</b>	0.510
GSC-6	0.624	0.563	0.526	<b>0.834</b>	0.602
EMA-1	0.325	0.282	0.553	0.312	<b>0.754</b>
EMA-2	0.441	0.391	0.600	0.347	<b>0.769</b>
EMA-3	0.383	0.369	0.568	0.328	<b>0.749</b>
EMA-4	0.552	0.523	0.552	0.548	<b>0.751</b>
EMA-5	0.588	0.568	0.582	0.525	<b>0.737</b>

#### 4.2. Hypotheses Testing

The relationships between the variables under investigation are shown by the full analysis of the direct-influencing hypotheses (H1, H2, and H3) and moderating hypotheses (H4, H5, and H6) examined in this study, as shown in Table 5 and Figure 2. The beta coefficients, t-values, and *p*-values are among the statistics in Table 5 that offer important insights into the importance and strength of these associations. Strong support for all the hypotheses is shown by the results.

**Table 5.** Structural Parameter Estimates.

	Hypotheses	Beta ( $\beta$ )	T-Statistics	p-Values	Results
H-1	GHC → CEP	0.482 ***	11.233	0.000	Accepted
H-2	GSC → CEP	0.153 ***	2.774	0.006	Accepted
H-3	GRC → CEP	0.187 ***	3.225	0.001	Accepted
H-4	GHC × EMA → CEP	−0.325 ***	8.051	0.000	Accepted
H-5	GSC × EMA → CEP	0.065 *	1.819	0.069	Accepted
H-6	GRC × EMA → CEP	0.103 **	2.271	0.023	Accepted

Note: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , and \*  $p < 0.10$ .



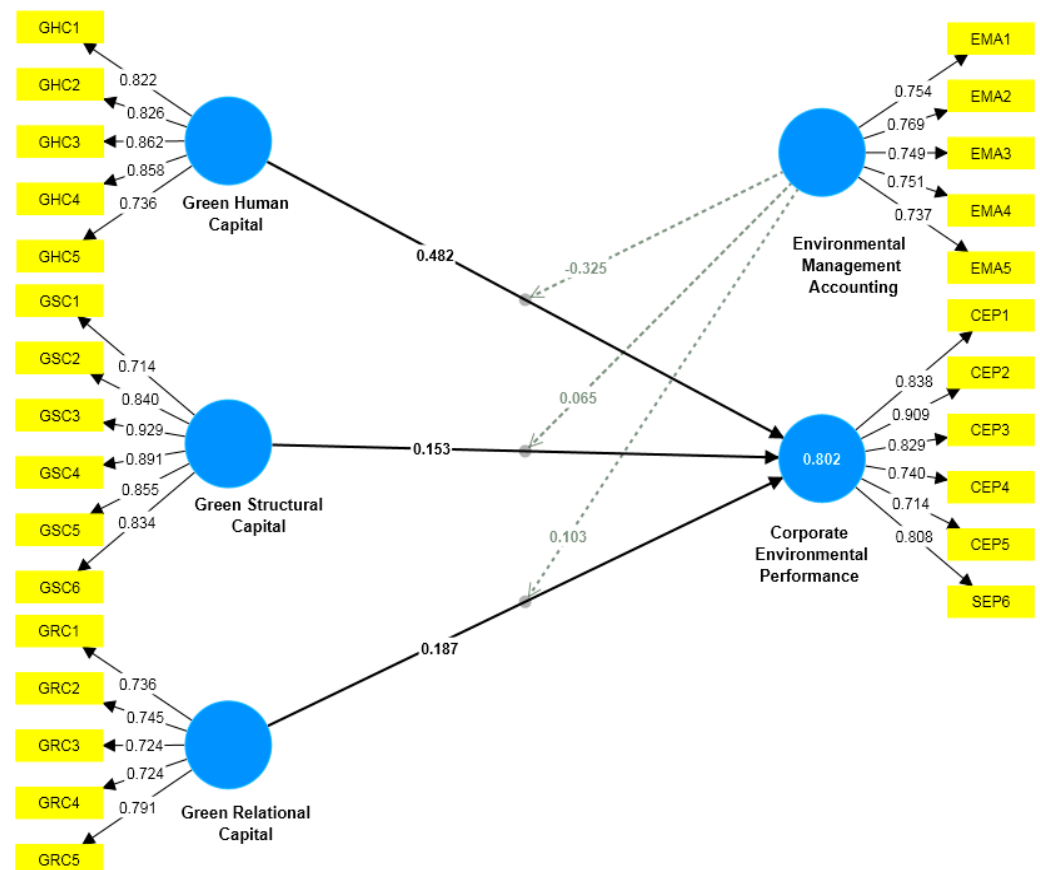


Figure 2. Final Research Model.

Regarding the direct-influencing hypotheses, the results of this study demonstrate a significant and positive influence of green intellectual capital components (GHC, GRC, and GSC) on corporate environmental performance (CEP). As shown in Table 5, the beta coefficients, t-values, and *p*-values indicate the strength and significance of these relationships. Specifically, GHC has a particularly strong positive impact on CEP, with a beta-value of 0.482, a t-value of 11.233, and a *p*-value of 0.000. Additionally, GRC and GSC also exhibit significant positive relationships with CEP, with beta-values of 0.187 and 0.153, respectively, and corresponding t-values and *p*-values indicating statistical significance. These findings support the direct-influencing hypotheses (H1, H2, and H3).

Furthermore, the results confirmed support for (H4, H5, and H6), which investigated the moderating effect of EMA on the relationship between CEP and GIC components. Regarding the moderating effect of the interaction between GHC and EMA on CEP (H4), the results demonstrated that EMA weakened the relationship between GHC and CEP, as shown in Figure 3. The outcome was negative and statistically significant (beta-values of -0.325, a t-value of 8.051, and a *p*-value of 0.000). On the other hand, H5, which looked into the moderating effect of the interaction between GSC and EMA on CEP, produced a positive and statistically significant result (beta-values of 0.065, a t-value of 1.819, and a *p*-value of 0.069). Figure 4 shows that EMA was found to increase the relationship between GSC and CEP. Additionally, with regard to the moderating effect of the interaction between GRC and EMA on CEP (H6), the results demonstrated a positive and statistically significant outcome (beta-values of 0.103, a t-value of 2.271, and a *p*-value of 0.023). As Figure 5 shows, EMA increased the relationship between GRC and CEP. The computed *R*<sup>2</sup> value was 80.2%, demonstrating a high level of quality and explanatory proportion for the model and implying that 80.2% of the variance in endogenous constructs is explained by the model.

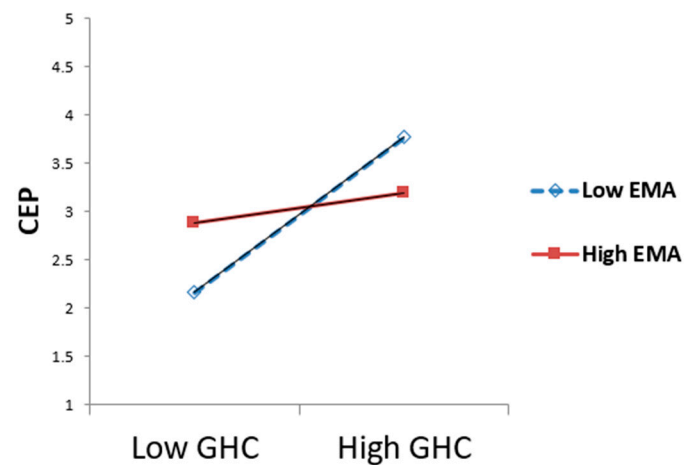


Figure 3. EMA moderates the relationship between GHC and CEP.

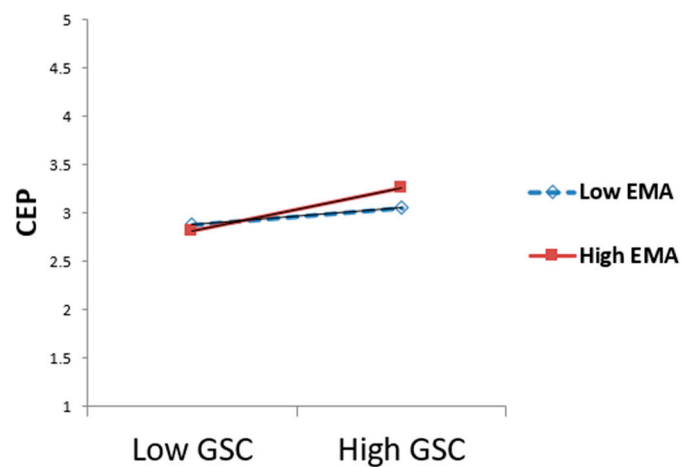


Figure 4. EMA moderates the relationship between GSC and CEP.

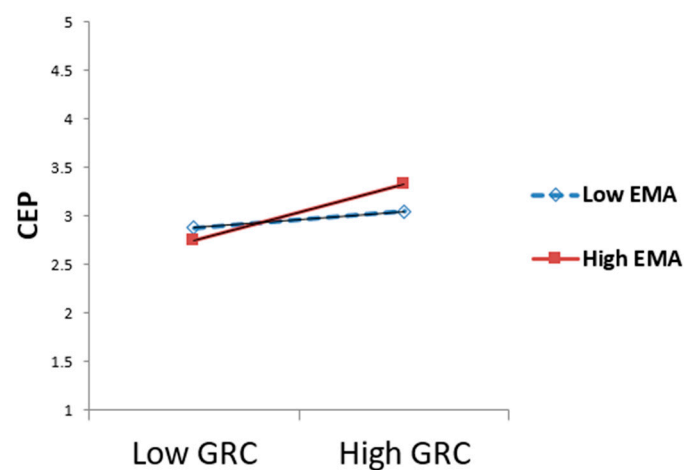


Figure 5. EMA moderates the relationship between GRC and CEP.

## 5. Discussion and Conclusions

The current study investigated the impact of all three GIC components, namely, GHC, GSC, and GRC on CEP based on the presence of EMA as a moderator in the Egyptian industrial sector. This sector represents one of the main sectors that the Egyptian government care for and enhance its control, accountability, and environmental impact ([Alnaim](#)

and Metwally 2024; Metwally et al. 2024). The results of this study revealed that there is a positive and significant impact of all GIC components on CEP. Hence, the first three hypotheses were all found to be acceptable. Additionally, it was discovered from the data that EMA had a negative effect on the association between GHC and CEP but had a positive impact on the relationship between GSC and GRC on CEP. The study model demonstrated a high level of quality and explanatory proportion, which was able to explain 80.2% of the variance in CEP.

Additionally, our research confirmed H1, showing that GHC had a favorable effect on CEP. We also discovered a strong positive correlation between GHC and CEP, which is consistent with the findings of previous studies (Mansoor et al. 2021; Shah et al. 2021; Asiaei et al. 2022a, 2022b; Asiaei et al. 2023; Buhaya and Metwally 2024). This result highlights the value of environmental knowledge and competency within an organization's workforce and how it is a crucial factor in determining effective and sustainable operations (Sheikh 2022). GHC is therefore a strategic asset that improves organizational ability to deal with environmental issues. Through training, information exchange, and utilizing staff experience, firms may invest in GHC and specialized skill development and promote creative thinking and the acquisition of critical environmental training. These initiatives support the development of CEP and the reduction of environmental risks. Empirical studies (Mansoor et al. 2021; Shah et al. 2021; Asiaei et al. 2022a, 2022b; Asiaei et al. 2023; Buhaya and Metwally 2024) confirm that, in the context of Egypt, GHC has a significant role in influencing corporate performance and environmental sustainability.

In addition, H2 was supported by this study's findings, which indicate the positive impact of GSC on CEP. Within the Egyptian context, the presence of GSC significantly improves environmental performance. Our results indicate that GSC is a critical determinant of a firm's enhanced environmental performance, consistent with previous studies (Mansoor et al. 2021; Shah et al. 2021; Asiaei et al. 2022a, 2022b; Asiaei et al. 2023; Buhaya and Metwally 2024). Previous studies have established a causal relationship between GSC and the development of a firm's environmental management capabilities, leading to enhanced CEP (Asiaei et al. 2022a, 2022b; Asiaei et al. 2023; Buhaya and Metwally 2024). In the context of green supply chains, organizations that strategically invest in environmentally-focused structural capital, such as information systems and knowledge management, can generate novel environmental value and achieve heightened sustainability performance (Asiaei et al. 2023; Buhaya and Metwally 2024).

Furthermore, H3 was confirmed by the current study results, where our empirical results provide strong evidence supporting the positive impact of GRC on CEP, consistent with prior studies (Mansoor et al. 2021; Shah et al. 2021; Asiaei et al. 2022a, 2022b; Sheikh 2022; Asiaei et al. 2023; Buhaya and Metwally 2024), where GRC plays a critical role in fostering greater environmental collaboration by carefully managing connections with key stakeholders, including suppliers and consumers (Buhaya and Metwally 2024). Prior research has emphasized the importance of businesses using internal and external networks to share environmental data, which may result in more effective goods and lower operating costs (Al-Khatib and Shuhaiber 2022; Wong et al. 2020). These findings demonstrate how important it is for Egyptian industrial firms to develop strategic connections with key stakeholders, since doing so creates distinctive added value and advances CEP considerably.

The results of this study support H4, H5, and H6, which makes the conclusions about the moderating effect of EMA noteworthy. As per the results, EMA exhibited a negative moderating effect in the association between GHC and CEP. Practically, the reason for this negative impact can be explained through observing that recently (after COVID-19) the Egyptian government has implemented stringent measures, including legislative reforms and innovative financing mechanisms, like green bonds. The country has also set ambitious targets in areas such as wind energy, electric transport, green hydrogen production, solar energy, and low-carbon initiatives (Buhaya and Metwally 2024; Metwally et al. 2024). As a response, many companies that did not have EMA before 2021 started new initiatives to have EMA and environmental strategies to comply to these changes in regulations (Alnaim

and Metwally 2024). Nevertheless, some companies are still not understanding the real rule of EMA in their operations, which leads to a negative impact on the overall environmental performance, especially for small and medium companies (Afolabi et al. 2023). Another reason may be sociological, as per institutional theory, governmental pressures may lead to decoupling in the isomorphism processes (Metwally and Diab 2021; Diab and Metwally 2019; DiMaggio and Powell 1983). This decoupling was apparent in that the environmental performance was reduced when EMA procedures and protocols were newly initiated in companies; employees then had to deal with it as a new regulation to be complied with, and started box ticking to inform company management and the government of that compliance.

Regarding how EMA moderates the relationships between GSC and CEP, as well as GRC and CEP, the results confirmed H5 and H6 showing a positive moderating role as EMA is supposed to enhance both financial and non-financial aspects of the environmental performance (Sari et al. 2021). This result extends the findings reached by Asiaei et al. (2022a) who proved a positive and significant direct impact of EMA on CEP and a mediating role of EMA in the Iranian context. In the Egyptian context, the results proved only a moderating role in the relationship between all GIC components and CEP. Nevertheless, our results stress the importance of contextual ramifications, as the varied cultural, legal, ethical, political, and behavioral contexts unique to each country add layers of complexity that influence how the inclusion of new systems impact the implementation processes, ultimately shaping the final performance outcomes (Metwally and Diab 2021; Metwally et al. 2022; Alnaim and Metwally 2024; Buhaya and Metwally 2024).

## 6. Implications, Limitations and Future Research Directions

This research offers valuable theoretical contributions via developing a conceptual model that examines the interrelationships between GHC, GSC, GRC, EMA, and CEP in the industrial sector of Egypt.

While earlier studies have examined the connection between GIC and GSCP and GIC and CEP, this research distinguishes itself by focusing on the implementation of environmental and management accounting and its related strategies and procedures, and to what extent Egyptian firms benefited from this implementation in terms of enhancing their CEP.

Grounded in a resource-based view (RBV), this study reinforces existing findings that suggest investing in GIC can enhance CEP. However, it emphasizes the significant role of GIC components in CEP. Additionally, this research sheds light on the link between social capital, structural and relational capital, and their interaction with environmental management and sustainability, an area deserving further academic exploration. Nevertheless, some findings deviate from the previous literature, particularly in revealing a negative impact of EMA in the relationship between GHC and CEP, which was explained through decoupling sociological norm. Moreover, this study succeeds in proving a moderating role of EMA against early studies that explained either direct impact on CEP or a mediating impact.

The implications of these findings extend to administrators, managers, and management accountants in the Egyptian industrial sector. This study confirms the positive impact of all GIC components on CEP, encouraging managers to invest in enhancing employee skills and experience to improve green capital and bolster sustainability and enhance their environmental performance. It is crucial to prioritize organizational policies that promote environmental preservation, incentivize innovative environmental thinking among employees, and document these innovations. Furthermore, this study highlights the moderating effect of EMA on the relationship between GIC components and CEP, suggesting the need for policymakers and managers to strategize on integrating green initiatives into organizational norms to address observed challenges. This can be achieved with more training on EMA and trying to involve all stakeholders in the implementation process, which should lead to enhanced CEP.

Moreover, this study has contributed to the literature as it demonstrates how GIC positively impacts CEP, aligning with findings from previous case studies (Asiaei et al. 2023; Boso et al. 2023; Bivona and Scirè 2024; Buhaya and Metwally 2024). Bivona and Scirè (2024) highlighted several essential drivers, including strong local engagement through community relationships, board members' commitment to ESG principles, management stability, and a phased approach to implementing ESG initiatives. The social and governance dimensions are crucial to achieving ESG goals, as these objectives require significant organizational shifts supported by senior leadership and executed across the enterprise (Eccles et al. 2014).

While the results of this study contribute to the literature and theory, it has several implications and faces certain limitations. Its reliance on cross-sectional data requires caution when generalizing findings, suggesting the potential benefits of employing longitudinal or panel data for a deeper understanding of construct relationships. The fact that cross-sectional studies only record data at one particular moment in time presents a serious obstacle to comprehending causal links. In assessing the moderating effects of EMA, this kind of research methodology could not adequately represent the dynamic character of how EMA practices change and impact organizational procedures over time. For example, implementing EMA may have long-term consequences that are not visible in a cross-sectional picture, since they may develop gradually. Because of this time constraint, the actual moderating function of EMA may be underestimated or misunderstood. Additionally, exploring diverse contexts, countries, and cultures can offer richer insights into the relationships between GIC and CEP. This can be achieved by integrating qualitative methods, such as interviews, with quantitative approaches to enrich future investigations. Moreover, future studies might explore intermediary concepts, like green innovation, organizational culture, external regulatory pressures or practices in green human resource management, delving deeper into their underlying causal relationships. Moreover, studies may concentrate on circular economy practices and SME sustainability challenges. This could provide a more comprehensive understanding of the topic by capturing nuanced opinions, insights, and contextual information that may not be adequately explained by quantitative data alone.

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