sustainability

MDPI

Article

The Moderating Role of Digital Environmental Management Accounting in the Relationship between Eco-Efficiency and Corporate Sustainability

Abeer M. Abdelhalim [1,2,*], Nahla Ibrahim [3] and Mohammed Alomair [3]

[1] Department of Accounting, Applied College, King Faisal University, Al-Ahsa 31982, Saudi Arabia
[2] Business Information Systems Department, Management Technology, Information Systems College, Port Said University, Port Said 42522, Egypt
[3] Department of Accounting, Faculty of Business Administration, King Faisal University, Al-Ahsa 31982, Saudi Arabia
* Correspondence: aabdelhalim@kfu.edu.sa

Abstract: In response to concerns about environmental issues and the role of manufacturing corporations in maintaining eco-efficiency, this study aimed to investigate the moderating role of digitally supported environmental management accounting (EMA) in the relationship between eco-efficiency and corporate sustainability performance. A quantitative approach was applied by using a survey distributed to a sample consisting of 77 individuals from senior and executive financial and operational positions in large Saudi manufacturing corporations. The findings of the linear regression analysis revealed that there is an insignificant direct relationship between eco-efficiency and corporate sustainability performance, while there is a significant moderating impact of EMA on the linkage between eco-efficiency and corporate environmental sustainability, and this significant moderating impact also applied to the linkage between digital applications and corporate environmental sustainability. This study provides good insights into the domain of environmental sustainability performance on the business scale in the Saudi context as an emerging economy, as it could be considered an innovative contribution to theoretical and practical aspects in the recent green issue adoption context; theoretically, it provides additional evidence of the role of digital EMA in improving environmental sustainability performance, and practically, the study findings can be beneficial for strategy and policymakers in corporations and regulators of environmental sustainability performance.

Keywords: eco-efficiency; digital technologies; environmental management accounting EMA; corporate environmental sustainability performance

Citation: Abdelhalim, A.M.; Ibrahim, N.; Alomair, M. The Moderating Role of Digital Environmental Management Accounting in the Relationship between Eco-Efficiency and Corporate Sustainability. *Sustainability* **2023**, *15*, 7052. https://doi.org/10.3390/su15097052

Academic Editor: Su-Yol Lee

Received: 19 March 2023
Revised: 17 April 2023
Accepted: 20 April 2023
Published: 23 April 2023

1. Introduction

Environmental threats have recently become a critical concern, as they are aggravated by harmful human practices in the environment, such as oil spills in the seas and oceans, industrial wastes, fossil fuel emissions, and residential trash. These factors have led to severe environmental pollution, climate change, and global warming and their consequent catastrophic impacts on the planet and the population. These environmental issues have attracted the attention of the media, as, over time, there has been a growth in public awareness, which prompted an increasing demand from stakeholders on organizations to adopt environmental strategies and practices that are safer and less harmful to the environment. Corporations everywhere in the world need to seriously consider environmental sustainability strategies and adopt practices and activities that can achieve better environmental performance [1].

Due to the mounting concerns about environmental impacts and the international community's pressures to mitigate these impacts, many organizations have begun to incorporate environmental issues into their business objectives. They are currently implementing

important initiatives aligned with strict government regulations, public awareness, and stakeholders' demands regarding environmental protection.

In addition to that, organizations have adopted environmental efficiency standards that revolve around minimizing environmental damage while simultaneously maximizing the efficiency of the company's production process. It is a management philosophy that has been adopted by green companies worldwide. Green companies use less water, materials, and energy and more recycling resources. This philosophy of environmental efficiency drives organizations to eliminate hazardous emissions or by-products and thus reduce their environmental impact. In other words, organizations working through the environmental efficiency criteria try to reduce their environmental burden [2].

Responding to environmental sustainability calls, organizations also adopted environmental management accounting (EMA) practices, with a demand shift from traditional management accounting to management accounting for sustainability. EMA is classified as a tool that can assist organizations in managing their environmental performance and providing and delivering environmental information to internal and external stakeholders. Environmental changes and threats increase the costs incurred by corporations; however, corporations cannot define and estimate these costs because they are generally hidden in overhead expenses. EMA could identify and help corporate leaders manage these costs more transparently to achieve environmental and economic benefits [3].

Overall, EMA can improve internal decision-making and save costs, as well as improve the corporate image and relationships with all stakeholders whilst improving financial performance; in other words, EMA practices can enhance corporations' current activities through the rational use of resources and the reduction in harmful environmental impacts [4].

The increase in calls for adopting environmental sustainability strategies in the business world has created gaps that have been highlighted in previous studies, which indicate the need for more research in this area. The findings of these studies are inconsistent regarding the extent of the need for EMA practices and their impact on the corporations' sustainability performance, especially if the application was in developing countries. This was one of the strong motivations for conducting the current study to investigate the moderating role of digital EMA in the relationship between eco-efficiency and corporate sustainability performance [5,6].

Saudi Arabia is one of the fast-growing economies in the Middle East; consequently, its business context is influenced by external challenges and pressures. Therefore, Saudi corporations should adapt to changes and follow the initiatives and practices of risk management and performance development, including those applied to green issues and challenges. As this has become one of the main interests of the Saudi government, and there are increasing calls and regulations for ensuring environmental sustainability performance, we conducted our study in the Saudi Arabia context.

This work adds to the literature in two ways. First, according to our information, this is the first effort to explore the factors affecting and moderating the role of EMA in the linkage between these factors and environmental sustainability performance in the Saudi Arabian context. This paper is structured as follows: Section 2 develops the theoretical foundation and the conceptual framework. Section 3 addresses the literature review and hypothesis development, and Section 4 describes the methodology and sample identification, followed by the results and further robustness checks in Section 5. Section 6 discusses the findings, Section 7 provides conclusions and contributions, and finally, Section 8 concludes with the limitations and implications of the study.

2. Theoretical Foundation and Conceptual Framework

We relied on two main theories to build our conceptual framework for this study; the first is institutional theory, which focuses on social pressures affecting organizations' strategies, activities, and performance. It is established as an authoritative guideline for

social behavior [7] and is used in the business environment as a basis for the systematic analysis of innovation [8].

Institutional theory is applied to business organizations as an approach to understanding business models and management strategies that respond to social rather than economic pressures to maintain conformity and legitimacy. Therefore, we used the concept of this theory to understand the impact of stakeholder calls and government regulations as external pressures regarding environmental issues on business corporations and how corporations respond to these pressures by embedding environmental sustainability standards into their strategies, operations, and performance indicators.

In addition, contingency theory provides an important approach based on the concept that there is no single fit for all circumstances [9]. Contingency refers to changes and contingent circumstances in the business environment; corporations should adapt accordingly to these changes and change their policies, systems, and strategies to avoid the negative impacts of external challenges and risks on corporate performance. Management accounting practices are actually one of the main applications of contingency theory [10].

Consequently, environmental management accounting according to contingency theory is considered a crucial development of management accounting practices to confront social pressures regarding embedding environmental sustainability into corporate performance.

Depending on the institutional theory and contingency theory approaches, we propose a conceptual framework (shown in Figure 1) to investigate the relationships between our study variables.

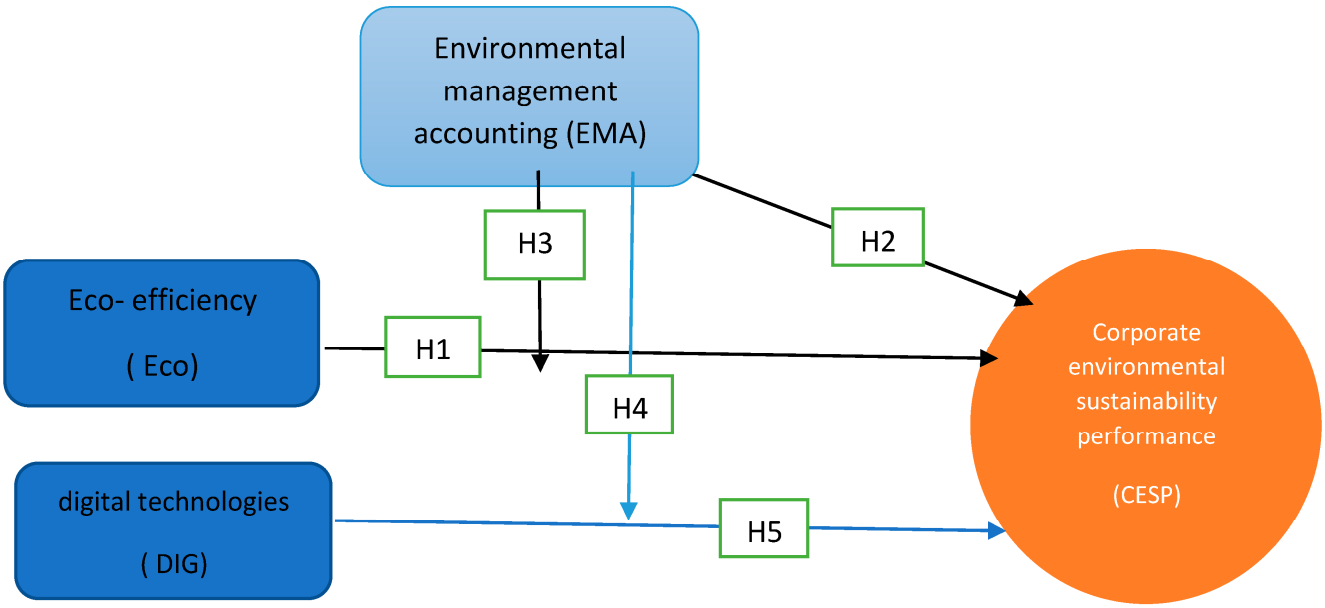

Figure 1. The conceptual framework of the research.

3. Literature Review and Hypothesis Development

3.1. Eco-Efficiency (Eco) and Corporate Environmental Sustainability Performance (CESP)

Environmentally sustainable development has been addressed in the Amsterdam Treaty and many other associations, such as the Carbon Disclosure Project (CDP) and the Global Reporting Initiative (GRI). They emphasize the importance of the integration of environmental issues into other strategies and state that improved environmental quality should become one of the main objectives at the macro and micro levels. To achieve this, information is needed to support an effective environmental strategy formulation that converts environmental sustainability into economic activity.

A study [11] indicated that the concept of eco-efficiency is the focus of research work and that corporations try to embed environmental sustainability into their strategies and activities as a response to stakeholders' and governments' pressures on this issue. The

authors tried to examine how SMEs see the eco-efficiency concept and its role in implementing sustainability strategies, and they defined four factors for implementing a sustainability strategy: the environmental management system, environmental knowledge, organizational culture, and environmental monitoring and control. The findings revealed that most SMEs still do not know a lot about existing sustainability strategies and environmental practices. However, they agree with the importance of integrating environmental sustainability into corporate strategies and practices to reduce the harmful impacts of their irrational use of natural resources and the wastes resulting from production processes, such as gas emissions, harmful chemical liquid, and solid wastes. Accordingly, we make an important note here regarding our study population and sample, as they were selected from large-sized production corporations, as we believe that, inconsistent with the findings of [11], large-scale corporations may take actions and initiatives to ensure their environmental sustainability performance development. There is another piece of evidence provided by [12] of the significant relationship between eco-efficiency and corporate sustainability through savings in the use of energy in their study corporations.

At the business level, corporations need to monitor and maintain their 'eco efficiency' through their operations and activities regarding resource allocation and water and energy consumption, as well as waste management; consequently, this will lead to achieving and improving corporate environmental sustainability performance. Therefore, we developed the following hypothesis:

Hypothesis 1 (H1). *There is a significant relationship between eco-efficiency and corporate environmental sustainability performance.*

3.2. EMA and Corporate Environmental Sustainability Performance (CESP)

There is proven evidence from many previous studies that EMA implementation has a positive impact on environmental performance [13–16], as they concluded that EMA is an important determinant of environmental performance [17]. It has been stated that environmental uncertainty has a strong role in the implementation of EMA practices; however, institutional pressures are the main driver of a firm's environmental strategy formulation. In addition, there are serial mediation effects of the environmental strategy and EMA practices on the firm's environmental performance. Moreover, [18] indicated that EMA practices enable corporations to achieve a competitive advantage and improve their overall performance.

The results of a previous study [19] showed that there is a significant impact of environmental strategies on companies' environmental performance, and environmental management accounting has a significant mediating role in their linkage. Furthermore, [20] indicated that there are many incentives for implementing EMA in corporations to achieve sustainable development, and they also stated that there are barriers and challenges to effectively implementing EMA, as there are no regulations or government restrictions on corporate environmental sustainability performance measures and reporting in Iraq. These findings are interesting for the authors, as the application was in a developing country, which is very similar to our application circumstances.

Based on the above arguments, and to contribute to the literature with new evidence of the impact of EMA practices on corporate environmental sustainability performance, we established the following hypothesis:

Hypothesis 2 (H2). *There is a significant impact of EMA practices on corporate environmental sustainability performance.*

3.3. Interaction between Eco-Efficiency and EMA

Eco-efficiency is a concept and strategy enabling the rational use of resources inputted by production processes needed to achieve and maximize economic objectives (e.g., profits and return on investment). Eco-efficiency aims to allow equitable use of natural resources

by current and future generations. In other words, it encourages corporations to become more environmentally responsible and profitable [21,22].

WBCSD (World Business Council for Sustainable Development https://docs.wbcsd.org/2006/08/EfficiencyLearningModule.pdf) has identified seven actions that can be taken by corporations to maintain their eco-efficiency: reduce the material intensity; reduce the energy intensity; reduce the dispersion of toxic substances; enhance recycling ability; maximize the use of renewables; extend product durability; and increase service intensity.

EMA is defined as the process of the identification, collection, analysis, and use of two types of information needed to support decision making: physical information on the resources used in economic activities, such as the flows and consumption of energy, water, materials, and wastes (PEMA), and monetary or financial information about environment-related costs and earnings (MEMA) (International Federation of Accountants 2005, International Guidance Document: Environmental Management Accounting) [4].

Then, we can say that there is a strong need for EMA practices to properly assess the level of eco-efficiency of the corporation and the environmental costs, as it links and interprets the material information into monetary information, so it can be easily evaluated and monitored [23]. According to IFAC (https://www.ifac.org/knowledge-gateway/contributing-global-economy/discussion/putting-focus-environmental-management-accounting), the data inputs that can be collected from the PEMA perspective include material inputs such as raw materials, packaging materials, operating materials, water, and energy; product outcomes such as products and by-products; and wastes such as solid waste, toxic waste, water waste, and gas emissions. In addition, it stated that the data inputs required for the MEMA perspective might include the material costs of products; material costs of non-products; waste and emission control costs; prevention and other environmental management costs; research and development costs; and other hidden costs. This means that eco-efficiency can work as a benchmark criterion, and EMA is the process of calculating the impacts of corporate actions and evaluating the outputs in light of eco-efficiency indicators to define where the corporation stands and how to achieve progress along the road [24].

Recently, stakeholders have started to evaluate a company based not only on economic indicators but also on how the corporation manages environmental issues as a main part of its performance and long-term value. The authors of [19] demonstrated that environmental management accounting has a positive moderating impact on firm value and stakeholder support. They showed that environmental management accounting is a vital requirement for eco-efficiency improvement, as it is used to minimize energy consumption, hazardous waste generation, and waste management costs to increase a company's economic value [25]. In other words, eco-efficiency is a relative and necessary guide, but not a sufficient requirement for corporations to achieve and improve corporate environmental sustainability, as it needs to be supported by other information systems, such as EMA or digital technologies supported by EMA.

Few recent studies have investigated the mediating and moderating roles of EMA in the relationships between other variables; for instance, ref. [26] provides strong evidence of the moderating role of environmental management accounting, as it strengthens the positive influence of sustainability performance and green innovation on firm value. Additionally, the findings of [12] revealed that EMA, measured in terms of eco-efficiency, has a positive impact on corporate sustainability, as they indicated that the high eco-efficiency performance of businesses reflects minimal energy use. Energy efficiency is unquestionably good for the environment, society, and businesses, and it helps businesses remain sustainable.

However, the EMA literature has overlooked its moderating role in the relationship between eco-efficiency and corporate environmental sustainability performance. Based on our previous discussion, we developed the next hypothesis:

Hypothesis 3 (H3). *EMA has a significant moderating impact on the relationship between eco-efficiency and corporate environmental sustainability performance.*

3.4. Digital Technologies (DIG) and Corporate Environmental Sustainability Performance (CESP)

Currently, available studies in the literature addressing the impact of digital transformation on corporate performance provide much evidence of the opportunities and challenges generated by new technology adoption. Digital information was examined as a moderator variable in very few studies and from different perspectives; for example, [27] provided empirical findings showing that organizational circular economy practices and sustainability performance are significantly influenced by fintech adoption, and that the circular economy practice works as a mediator in the linkage between fintech adoption and sustainability performance.

A study [28] stated that EMA plays an important role in the relationship between innovations and firm performance. When firms adopt innovative systems, they increase their chances and capabilities to improve their EMA system; consequently, they can support decisions more effectively, which is finally reflected in better financial performance. In other words, EMA plays a positive mediating role in the relationship between innovation and firm performance.

In the same context, and due to the lack of empirical evidence of the moderating impact of EMA on the linkage between digital technology adoption and corporate environmental sustainability performance, we developed the following hypothesis:

Hypothesis 4 (H4). *Digital technologies have a significant impact on corporate environmental sustainability performance.*

3.5. Interaction between Digital Technologies (DIG) and Environmental Management Accounting (EMA)

Based on a review of the literature, many studies have examined the impacts of digital transformations in the business world, such as big data analytics, the Internet of Things, algorithms, and artificial intelligence applications, on management accounting practices. In addition, there is much evidence of a significant impact of those new technologies on management accounting and, consequently, on corporate performance, as it improves the functionality of management accounting, especially in responding to contextual challenges and risk management, but there is a scarcity of studies that examined the relationship between digital techniques, or what is called Industry 4.0, and environmental management accounting and its impact on corporate sustainability performance [27,29,30].

Here, we will discuss a few studies related to the impact of digital technologies on EMA [30] and assess the role of the value creation potential—which is one of the distinguished characteristics—of digital technologies and solutions (Industry 4.0) and its contribution to creating sustainable value for corporations. This study depended on the 17 Goals set out by the United Nations Sustainable Development (SDGs) and defined the characteristics of Industry 4.0. The study evaluated the macro and micro effects of these technologies and provided suggestions for how to exploit the characteristics of digital technologies to achieve sustainability. However, it did not explicitly address the role of environmental management accounting applications or sustainability accounting in the relationship between digital technologies and corporate sustainability [31].

The study in [9] indicated that the development of Industry 4.0 has achieved many advantages, such as reducing errors, improving product quality, completing routine tasks and removing human power for complex and/or dangerous tasks, and providing customers with products with a competitive speed and flexibility. This study emphasized the importance of the resource efficiency concept; however, the authors stated that the process of understanding how to integrate Industry 4.0 technologies in achieving corporate sustainability is still in its infancy or still undeveloped. To address this problem, the authors show that there is a need for more investigation into how to integrate Industry 4.0 technologies—through environmental management accounting—into the development of corporate sustainability. Their study concluded that there are potential improvements in the environmental management accounting outputs when using digital technologies,

represented by improved data quality in terms of timing, accuracy, reliability, and comparability. Additionally, they can improve the prediction abilities and thus the support of decision making and improve the level of information transparency and credibility. Overall, this paper provided examples of how these potential improvements could contribute to improving sustainable accounting and its outputs, but it did not provide any experimental evidence to prove its claims.

In another study [32], the authors explore what technical features in Industry 4.0 can enable reliable and relevant measurements of sustainability accounting in the model of the triple bottom line, and how corporations can use these features in practice to develop the functionality of sustainability accounting. The study was performed in small-scale industrial companies in India. The findings from their interview discussions showed that corporate sustainability was not measured properly and that the participants in the interview showed fear of the intensive investment in digital technologies and solutions of Industry 4.0 due to the low maturity of artificial intelligence applications and its limited application in accounting. Thus, they expected low returns from its use. Accordingly, Khan indicated that the findings of an investigation of the relationships between digital technologies and sustainability accounting may differ according to the application environment, especially if there are barriers to low investment in technology and a lack of sufficient and binding regulations to report on corporate sustainability.

Many research gaps need to be filled through future research, as mentioned by [8]. These include exploring and defining how Industry 4.0 technologies affect the development of environmental management accounting applications to become more accurate and relevant, produce high-quality outputs, and implement timely internal and external environmental reporting. They also need to be tested with various case applications in different economic sectors, for different firm sizes, and with different levels of decision support, as well as at the level of the main activities within the corporation, such as supply chains.

Based on the previous discussion, it is strongly predicted that digital technologies can enhance EMA practices and their role in improving corporations' environmentally sustainable performance. Thus, we propose the following hypothesis:

Hypothesis 5 (H5). *EMA has a significant moderating impact on the relationship between digital technologies and corporate environmental sustainability performance.*

4. Methods and Research Design

As a quantitative approach in this study, a purpose-designed questionnaire was used for collecting the data. The variable measurement items were formulated based on previous studies, as presented in Appendix A. A 5-point Likert scale with anchors that ranged from one (1), depicting strongly agree, to five (5), depicting strongly disagree, was employed for answering questions. The primary questionnaire version was sent for review to three academicians and three senior corporate managers as professionals in the domain of environmental sustainability performance. The questionnaire items were adjusted to their final edition based on their comments, and then the questionnaire was initially tested on a small scale for reliability and validity confirmation purposes. It is worth mentioning that the respondents' communication language was Arabic, so a language professional translated the questionnaire and responses from English to Arabic and vice versa, in addition to proofreading and revision. The translated questionnaire was tested on 14 Saudi corporate senior managers, executives, and accountants to ensure questionnaire clarity and to test the constructs' reliability, following the suggestion of [33]. The constructs' Cronbach's alphas all exceeded 0.70, which, according to [34], indicates a good reliability level.

On the basis of an exploratory study of the annual reports and websites of Saudi manufacturing corporations, the sample of this study was chosen from large manufacturing Saudi corporations (in terms of total investments not less than SAR one billion), and it consisted of 33 corporations that disclosed their environmental sustainability performance or activities. The respondents consisted of senior operations and financial managers,

executives, and accountants, as these individuals can provide information about the current study variables. Their contact information was collected from corporations' websites, and then the questionnaire was sent to the respondents via email and WhatsApp, including a cover letter that contained the study objective and purpose and a short list of main terms' definitions, in addition to the researcher's contact information for any inquiries or explanations of any mysteries. A total of 180 questionnaire surveys were distributed; however, the number of valid received responses was 77, with a response rate of 43%, which constitutes the sample and is considered a reasonably representative sample of the study population; thus, the researcher does not believe that non-response bias is a problem.

5. Data Analysis and Results

This study used the ordinary linear regression approach for hypothesis testing, applied in two steps: first without the interaction term and then with the interaction term to test for potential moderation [35].

The analysis tested two-way interactions by regressing the dependent variable Y (environmental sustainability performance corporations) on the independent variable X (eco-efficiency) and T (digital technologies), the moderator variable Z (environmental management accounting), the product (interaction) term of X and Z (XZ), and the product of T and Z (TZ) [36].

The model tested is shown below:

$$Y = b_0 + b_1X + b_2T + b_3\ Z + b_4XZ + b_5\ TZ + \epsilon$$

To assess the validity of the model constructs, the criterion from [37] was used to assess the degree of shared variance between the latent variables of the model. According to this criterion, the Average Variance Extracted (AVE) and Composite Reliability (CR) can assess the convergent validity of the measurement model. AVE measures the level of variance captured by a construct versus the level due to measurement error; values above 0.7 are considered very good, whereas a level of 0.5 is acceptable. CR is a less biased estimate of reliability than Cronbach's alpha: the acceptable value of CR is 0.7 and above. The results in Table 1 show that the CR values of all constructs are more than 0.7.

Table 1. Assessment of the measurement model.

Construct/Indicators	Standard Loading	Cronbach's A	AVE	CR
Eco-efficiency	0.999	0.84	0.512	0.87
EMA	0.971	0.88	0.507	0.90
Digital technologies	0.683	0.76	0.501	0.79
Environmental sustainability	0.998	0.91	0.538	0.93

Table 2 presents a descriptive analysis of the variables used in this study. The mean of the independent variable (eco-efficiency) was 1.99, which means that respondents mostly and strongly agreed with the variable items, while the other independent variable's (digital technology) mean was 3.29, which means that there is moderate usage of digital applications in the study corporations. The moderating variable's (EMA) mean was 2.39, which indicates that the practices of EMA in the study corporations are active to a good extent. Moreover, the awareness and embedding of corporate environmental sustainability seem to occur at a good rate, as the mean of the dependent variable was 1.89.

The results of the linear regression of the tested hypotheses are shown in Table 3. The coefficient value signifies how much the mean of the dependent variable changes given a one-unit shift in the independent variable while holding other variables in the model constant. In the first stage of the analysis, the direct effects of independent and control variables were investigated, and the results indicated that there is no effect of eco-efficiency on corporate environmental sustainability, as the p-value is more than 0.05. Therefore, H1 is not supported, and the same result applies to H4, related to the effect of digital

technologies on corporate environmental sustainability. However, EMA has a significant effect on corporate environmental sustainability (p-value < 0.01). There are no significant effects of control variables (corporate size, manufacturing sector, and corporate age), except for the corporate size (p-value < 0.05), which means that a large corporate size in terms of investment volume (more than SAR 1 billion on average) has a significant impact on environmental sustainability performance.

Table 2. Descriptive statistics of main variables.

	Descriptive Statistics										
	N	Min.	Max.	Mean	Std. Deviation	Skewness		Kurtosis		Quartiles	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error	Q1	Q3
Eco-efficiency	77	1.14	3.00	1.9907	0.48019	0.115	0.274	−1.008	0.541	1.5714	2.2857
EMA	77	1.70	3.40	2.3935	0.37323	0.336	0.274	0.030	0.541	2.1000	2.6000
Corporate sustainability	77	1.18	2.82	1.9231	0.34521	0.689	0.274	0.239	0.541	1.6364	2.0909
Digital technologies	77	2.25	4.25	3.2987	0.45890	0.137	0.274	−0.479	0.541	3.0000	3.6250
CST	77	1.00	4.00	1.8052	1.00051	0.729	0.274	−0.967	0.541	1.0000	3.0000
CMF	77	1.00	5.00	2.3377	1.26294	0.860	0.274	−0.207	0.541	1.0000	3.0000
CA	77	1.00	3.00	1.8052	0.77865	0.358	0.274	−1.258	0.541	1.0000	2.0000
Valid N (list-wise)	77										

Table 3. Results of hypothesis testing by linear regression analysis.

Part 1: Direct Effects of Independent and Control Variables on the Dependent Variable							
		Coefficients					
Hypothesis		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Result
		B	Std. Error	Beta			
H1	(Constant)	1.705	0.168		10.142	0.000	Rejected
	Eco-CESP	0.094	0.082	0.131	1.147	0.255	
H2	(Constant)	1.228	0.219		5.620	0.000	Supported
	EMA-CESP	0.273	0.089	0.336	3.085	0.003	
H4	(Constant)	1.815	0.163		9.092	0.000	Rejected
	DIG-CESP	0.089	0.079	0.126	1.223	0.164	
	(Constant)	1.980	0.129		15.305	0.000	
	CST	−0.108	0.060	−0.312	−1.794	0.045	
	CMF	0.009	0.048	0.032	0.181	0.857	
	CA	0.067	0.103	0.151	0.653	0.516	
Part 2: Results of moderating variable effect							
		Coefficients					
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Result
		B	Std. Error	Beta			
H3	(Constant)	1.190	0.242		4.922	0.000	Supported
	ECO	0.031	0.082	0.043	0.375	0.709	
	EMA	0.264	0.093	0.324	2.848	0.006	
a. Dependent Variable: CESP							
		Coefficients					
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Result
		B	Std. Error	Beta			
H5	(Constant)	1.346	0.182		7.395	0.000	Supported
	DIG	−0.004	0.080	−0.005	−0.045	0.964	
	EMA	0.218	0.058	0.420	3.760	0.000	

In the next stage of the analysis, the moderating effect of EMA on two relationships, eco-efficiency and corporate environmental sustainability (H3), was investigated, and the other one is the relation between digital technologies and corporate environmental sustainability (H5). The results in part 2 of Table 3 indicate that the interaction of EMA with eco-efficiency and digital technology is significant in corporate environmental sustainability,

as the *p*-values were 0.006 and 0.000, respectively, which means that both H3 and H5 are supported.

To reduce outlier effects in the linear regression models and confirm the effects of our variables, we used robust regression (results shown in Table 4) [38], as it is an alternative to least-squares regression when data are contaminated with outliers or influential observations, and it can also be used to detect influential observations [37].

Table 4. Results of hypothesis testing by robust regression.

	Coefficients		
	Value	Std. Error	T value
(intercept)	1.645	0.168	9.800
eco	0.107	0.082	1.307
Rim formula = ECO − CESP; residual standard error: 0.28667; degrees of freedom: 75.			
	Coefficients		
	Value	Std. Error	T value
(intercept)	0.434	0.187	3.850
dig	0.092	0.080	0.623
Rim formula = DIG − CESP; residual standard error: 0.28667; degrees of freedom: 74.			
	Coefficients		
	Value	Std. Error	T value
(intercept)	2.762	0.088	5.800
ECO	0.031	0.080	3.375
EMA	0.264	0.091	3.848
Rim formula = DIG − CESP; residual standard error: 0.28667; degrees of freedom: 75.			
	Coefficients		
	Value	Std. Error	T value
(intercept)	1.073	0.168	5.485
DIG	−0.005	0.080	3.234
EMA	0.218	0.058	3.331
Rim formula = DIG − CESP; residual standard error: 0.28667; degrees of freedom: 75.			

By comparing the values and standard errors of the variables between linear and robust regression, it can be noticed that they are the same in some coefficients and slightly different in other ones, which means that there are unbiased standard errors of OLS coefficients under heteroscedasticity.

6. Discussion of Findings

In our study, we focused on investigating the role of environmental management accounting in the relationship between eco-efficiency and corporate environmental sustainability performance, in addition to its moderating role in the linkage between digital applications adopted in the sample corporations and their environmental sustainability performance. The results of the regression analysis show that there is an insignificant direct effect of eco-efficiency and the environmental sustainability performance of the corporations (H1), and that is consistent with what we expected earlier, that is, eco-efficiency as a management approach cannot solely affect the environmental performance, and it needs to be translated into actions and activities of monitoring and evaluating the allocation of resources, energy consumption, and waste management processes so that it can be reflected in environmental performance indicators. In the same context, the results did not support a direct relationship between digital applications and environmental sustainability performance (H2), and this could be explained by the fact that no environmental performance indicators directly related to digital applications had been adopted in the corporations. For the third direct path between EMA and corporate environmental sustainability performance (CESP) (H4), the results supported the direct significant effect of EMA on CESP, which is inconsistent with the findings of many previous studies [2–4].

Then, we examined the combined effect of eco-efficiency and EMA on CESP (H3), and it was supported by the findings, which means that EMA could integrate the eco-

efficiency criterion to put its standards into sustainable activities, which can be continuously monitored and evaluated (in financial and non-financial or physical terms) to achieve and develop corporate environmental performance.

The fifth hypothesis related to the moderating role of EMA in the relation between digital applications and CESP was supported by the regression results, and this seems reasonable, as there is extensive evidence in the previous literature of the positive significant effect of digital applications on management accounting practices, and our study supports the significant effect of EMA on CESP, which means that integration between EMA and digital software may play a crucial role in the development of environmental sustainability performance.

7. Conclusions, Contributions, and Implications

This study could be a very useful application of both institutional and contingency theories, as it provides good evidence that may facilitate the development of corporate environmental sustainability performance in response to the more social pressures with regard to green issues, and embedding eco-efficiency into corporate operational planning and execution and setting environmental sustainability performance as crucial complementary parts of corporate performance. On the other hand, eco-efficiency as an environmental sustainability criterion cannot be activated without a contingent information system such as EMA. Taking into consideration the increasing levels of uncertainty regarding green issues and technology, turning the criteria of eco-efficiency into actions and activities that facilitate environmental performance measurement, monitoring, and evaluation.

Consequently, the findings of this study supported the significant moderating role of EMA in the linkage between eco-efficiency and corporate environmental sustainability performance, which means that EMA plays a critical role in the integration of eco-efficiency standards with the improvement in CESP, inconsistent with [17,39].

Moreover, the findings indicated that there is a significant moderating role of EMA in the relationship between digital applications and corporate environmental sustainability. This finding is aligned with that reported by recent research [40,41], which means that digital applications, such as big data analytics and business intelligence systems, improve the capabilities of environmental management accounting practices so that they become more accurate, better relevant, produce high-quality outputs, and implement timely internal and external environmental reporting, thus leading to better environmental sustainability performance.

In addition, the empirical findings of the current research revealed that large manufacturing corporations are likely to achieve better environmental sustainability performance, as they can invest more in digital applications and afford the overheads of recycling used resources and properly managing wastes. This is especially relevant in developing economies such as Saudi Arabia, where the regulations of environmental sustainability are still in their infancy [42].

As we mentioned earlier, the previous literature stated that EMA implementation is an important determinant of environmental performance [13,42–44]. However, there are research gaps concerning the impact of other factors on EMA application and its role in enhancing corporate environmental sustainability, and there is a need for more evidence in different contexts using different methodologies. Therefore, this study tried to fill part of the research gap by providing new evidence of the moderating impact of EMA on the linkage between eco-efficiency and environmental sustainability performance, and on the linkage between digital applications and environmental sustainability performance in Saudi manufacturing corporations as one of the emerging economy contexts.

8. Limitations

Any research is bound to have limitations, and such limitations can pave avenues for future studies to fill further research gaps. In this study, our main limitations are the following:

- The focus was on large manufacturing corporations in the Saudi Arabia context and other similar developing countries and economies, so the findings can only be generalized to companies in these same conditions.
- As the consideration of environmental sustainability performance on the business scale is still in the beginning stage in the Saudi context, our sample was 33 manufacturing corporations and was based only on the findings of an exploratory study conducted to identify the sample size, so future research can investigate the same relationships on larger scales to confirm findings.
- This study focuses only on large manufacturing corporations, as they are likely to be able to afford the costs and set flexible strategies to enhance environmental sustainability performance; therefore, SMEs could be the basis of future studies in the same domain.
- We focused only on manufacturing corporations, as they use the most resources, consume the most energy, and generate the most waste; however, other economic sectors need to be investigated from the perspective of environmental sustainability performance and the factors influencing it.

Author Contributions: Conceptualization, A.M.A.; Methodology, N.I.; Formal analysis, M.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research project was supported by the Institutional Funding Track 2022 provided by the Saudi Ministry of Education to King Faisal University, and the grant number is INST147.

Informed Consent Statement: Not applicable.

Data Availability Statement: The study data are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Variable measurements.

Variable	Code	Description	Measured Items	Data Sources from Previous Studies
Eco-efficiency	ECO	Concept and strategy enabling the rational use of resources inputted by production processes needed to achieve and maximize the economic objectives	• Reducing material requirements for goods • and services • Reducing the energy intensity of goods and • services • Reducing toxic • dispersion • Enhancing material • recyclability • Maximizing the sustainable use of renewable resources • Extending product durability • Enhancing waste management	• Menoni, M., and Morgavi, H. (2014) [23] • Nikolaou, I. E., and Matrakoukas, S. I. (2016) [24]
Environmental Management Accounting	EMA	Process of the identification, collection, analysis, and use of two types of information needed to support decision making: physical information on resources used in economic activities, such as flows and consumption of energy, water, materials, and wastes, in addition to monetary or financial information about environment-related costs and earnings.	**A** **Awareness of EMA** ✓ An accounting system that quantifies water and energy usage ✓ An accounting method that covers all areas of accounting that may be affected by the business response to environmental issues ✓ An information system that separately reports resource usage, e.g., energy, water, wood ✓ The provision of recycling facilities and energy-saving measures in the workplace ✓ A project appraisal technique for assessing the environmental impact of new 'investment' **B** **EMA practices** ✓ Financial Environmental Measures, e.g., Costs of Energy Used Per Annum, such as actual costing vs. standard costing and target costing ✓ Non-Financial Environmental Measures, e.g., the amount of Energy Used Per Annum, such as defined quantities of resources needed for processes, energy consumption rates, wastes, and plans for their recycling ✓ Performance Measurement Appraisal and Reporting ✓ Information Systems Support Data Input and Information Provision	• Bennett M. et al. 2011 [15] • Ferreira A. et al. 2010 [16] • Ramli A. and Ismail M. S., 2013 [18]
Digital technology applications	DIG		• Big data analytics • Artificial intelligence or algorithm applications in management accounting • Business intelligence (BI) • ERP systems	• Burritt, R.; Christ K., 2016 [29] • Siddik A., Yong L. and Rahman N., (2023) [27]

Table A1. *Cont.*

Variable	Code	Description	Measured Items	Data Sources from Previous Studies
Corporate environmental sustainability performance	CESP	An approach to conducting business that creates sustainable, long-term shareholder, employee, consumer, and societal value by pursuing responsible environmental strategies	Q4. Do you integrate environmental issues, e.g., energy usage, water usage, or recyclability when specifying or defining new projects Q4-a. What evaluation methods are used? • Differential costs • Standard costs • Eco-efficiency benchmarking • ABC costing Q5. Do you monitor the following environmental issues? • Energy Consumption • Water Usage • Stationery (Excl. Paper) • Paper Recycling • Paper Usage • Recycling, e.g., Plastics, Bottles, Tyers • Pesticides • Paint and Solvent Usage Q6. Does your corporate set quantitative targets (e.g., to reduce the energy used by 5% over the next five years) for the following environmental issues? Q7. Does your corporate have strategic plans to achieve the environmental sustainability objectives and requirements? Q8. Does your department have procedures in place to monitor practices known to be harmful to the environment? • Ozone: Depletes Financial • Toxic Substances-Black List Consumption • Toxic Substances-Red List • Tropical Hardwood Usage Q9: Do you report regularly to your direct manager about rates of resources and energy consumption and related problems? Q10: Do you report (even in a narrative way through your website or social media accounts) externally to the stakeholders about the environmental sustainability performance and take their feedback into account in future planning?	• Tiwari, K.; Khan, M.S., 2020 [32] • Pratiwi et al. 2020 [12]
Control variables: - Corporate size - Corporate manufacturing type - Corporate age	CS CMT CA		Profile questions	

References

1. De Sousa Jabbour, A.B.L.; Jabbour, C.J.C.; Foropon, C.; Filho, M.G. When titans meet—Can Industry 4.0 revolutionize the environmentally-sustainable manufacturing wave? The role of critical success factors. *Technol. Forecast. Soc. Chang.* **2018**, *132*, 18–25. [CrossRef]
2. Burritt, R.L.; Saka, C. Environmental management accounting applications and eco-efficiency: Case studies from Japan. *J. Clean. Prod.* **2006**, *14*, 1262–1275. [CrossRef]
3. Burritt, R.L.; Herzig, C.; Schaltegger, S.; Viere, T. Diffusion of environmental management accounting for cleaner production: Evidence from some case studies. *J. Clean.* **2019**, *224*, 479–491. [CrossRef]
4. Fuzi, N.M.; Habidin, N.F.; Effendy, S. Environmental management accounting practices and environmental performance for the Malaysian manufacturing industry. *Int. J. Acad. Res. Bus. Soc. Sci.* **2016**, *6*, 2222–6990. [CrossRef]
5. Global Sustainability Standards Boards. GRI 205: Anti-Korupsi 2016. Available online: https://www.globalreporting.org/standards/media/1536/bahasa-indonesia-gri-205-anti-corruption-2016.pdf (accessed on 18 March 2023).
6. World Business Council for Sustainable Development. Environmental and Sustainability Management Accounting Network. Available online: https://docs.wbcsd.org/2016/09/InternationalSustainability-Accounting-Symposium-booklet.pdf (accessed on 18 March 2023).
7. Meyer, J.W.; Rowan, B. Institutional organizational: Formal structure as myth and ceremony. *Am. J. Sociol.* **1977**, *83*, 340–363. [CrossRef]
8. Geels, F.W. Ontologies, Socio-Technical Transitions (to Sustainability), and the Multi-Level Perspective. *Res. Policy* **2010**, *39*, 495–510. [CrossRef]
9. Fiedler, F.E. A Contingency Model of Leadership Effectiveness. In *Advances in Experimental Social Psychology*; Academic Press: Cambridge, MA, USA, 1964; Volume 1, pp. 149–190. [CrossRef]
10. Otley, D.T. The contingency theory of management accounting: Achievement and prognosis. *Account. Organ. Soc.* **1980**, *5*, 413–428. [CrossRef]
11. Vásquez, J.; Carlos, S.; Bruno, E.F.R.; Priarone, P.C.; Settineri, L. A conceptual framework for the eco-efficiency assessment of small- and medium-sized enterprises. *J. Clean. Prod.* **2019**, *237*, 117660. [CrossRef]
12. Pratiwi, Y.N.; Meutia, I.; Syamsurijal, S. The Effect of Environmental Management Accounting on Corporate Sustainability. *Bus. Rev.* **2020**, *11*, 43–49. [CrossRef]
13. Yu, W.; Ramanathan, R. An empirical examination of stakeholder pressures, green operations practices, and environmental performance. *Int. J. Prod. Res.* **2015**, *53*, 6390–6407. [CrossRef]
14. Zhu, Q.; Sarkis, J.; Lai, K.H. Institutional-based antecedents and performance outcomes of internal and external green supply chain management practices. *J. Purch. Supply Manag.* **2013**, *19*, 106–117. [CrossRef]
15. Bennett, M.; Rikhardsson, P.; Schaltegger, S. Adopting Environmental Management Accounting: EMA as a Value-adding Activity. In *Review of Management Accounting Research 2011*; Palgrave Macmillan: London, UK, 2011; pp. 53–84. [CrossRef]
16. Ferreira, A.; Moulang, C.; Hendro, B. Environmental management accounting and innovation: An exploratory analysis. *Account. Audit. Account. J.* **2010**, *23*, 920–948. [CrossRef]
17. Kong, Y.; Javed, F.; Sultan, J.; Hanif, M.S.; Khan, N. EMA Implementation and Corporate Environmental Firm Performance: A Comparison of Institutional Pressures and Environmental Uncertainty. *Sustainability* **2022**, *14*, 5662. [CrossRef]
18. Ramli, A.; Ismail, M.S. Environmental Management Accounting Practices: A Survey of ISO 14001 Certified Malaysian Organizations. *J. Energy Technol. Policy* **2013**, *3*, 2224–3232.
19. Solovida, G.T.; Latan, H. Linking environmental strategy to environmental performance: The mediation role of environmental management accounting. Sustainability Accounting. *Manag. Policy J.* **2017**, *8*, 595–619. [CrossRef]
20. Thabit, T.H.; Laith, K.I. Implementation of Environmental Management Accounting for Enhancing the Sustainable Development in Iraqi Oil Refining Companies. In Proceedings of the 3rd Scientific Conference of Administration and Economic, Anbar, Iraq, 28 March 2019.
21. Caiado, R.G.G.; Dias, R.D.F.; Mattos, L.V.; Quelhas, O.L.G.; Filho, W.L. Towards sustainable development through the perspective of ecoefficiency-A systematic literature review. *J. Clean. Prod.* **2017**, *165*, 890–904. [CrossRef]
22. Salem, M.A.; Hasnan, N.; Osman, N.H. Can eco-efficiency represent corporate environmental performance? *Int. J. Humanit. Soc. Sci.* **2011**, *1*, 182–187.
23. Menoni, M.; Morgavi, H. Is eco-efficiency enough for sustainability? *Int. J. Perform. Eng.* **2014**, *10*, 337–346.
24. Nikolaou, I.E.; Matrakoukas, S.I. A framework to measure the eco-efficiency performance of firms through EMAS reports. *Sustain. Prod. Consum.* **2016**, *8*, 32–44. [CrossRef]
25. Meutia, I.; Ramadhani, M.; Adam, M. Does Eco-Efficiency Improve the Financial Performance of Manufacturing Companies in Indonesia? *J. Din. Akunt. Dan Bisnis* **2019**, *6*, 137–150. [CrossRef]
26. Damas, D.; Tarisa, B. The Moderating Role Of Environmental Management Accounting On Firm Value. *J. Akunt. Trisakti* **2022**, *9*, 281–306. [CrossRef]
27. Siddik, A.B.; Yong, L.; Rahman, M.N. The role of Fintech in circular economy practices to improve sustainability performance: A two-staged SEM-ANN approach. *Environ. Sci. Pollut. Res.* **2023**, 1–22. Available online: https://link.springer.com/article/10.1007/s11356-023-25576-7 (accessed on 18 March 2023).

28. Chaudhry, N.I.; Asad, H.; Hussain, R.I. Environmental innovation and financial performance: Mediating role of environmental management accounting and firm's environmental strategy. *Pak. J. Commer. Soc. Sci. (PJCSS)* **2020**, *14*, 715–737.
29. Burritt, R.; Christ, K. Industry 4.0 and environmental accounting: A new revolution? *Asian J. Sustain. Soc. Responsib.* **2016**, *1*, 23–38. [CrossRef]
30. Stock, T.; Obenaus, M.; Kunz, S.; Kohl, H. Industry 4.0 as an enabler for sustainable development: A qualitative assessment of its ecological and social potential. *Process Saf. Environ. Prot.* **2018**, *118*, 254–267. [CrossRef]
31. Porter, M.E.; Heppelmann, J.E. How digital, connected products are transforming companies. *Harv. Bus. Rev.* **2015**, *93*, 96–114.
32. Tiwari, K.; Khan, M.S. Sustainability accounting and reporting in the industry 4.0. *J. Clean.* **2020**, *258*, 120783. [CrossRef]
33. Dwivedi, M.; Laddha, N.C.; Arora, P.; Marfatia, Y.S.; Begum, R. Decreased regulatory T-cells and CD 4+/CD 8+ ratio correlate with disease onset and progression in patients with generalized vitiligo. *Pigment. Cell Melanoma. Res.* **2013**, *26*, 586–591. [CrossRef]
34. Hair, J.F.; Risher, J.J.; Sarstedt, M.; Ringle, C.M. When to use and how to report the results of PLS-SEM. *Eur. Bus. Rev.* **2019**, *31*, 2–24. [CrossRef]
35. Aiken, L.S.; West, S.G. *Multiple Regression: Testing and Interpreting Interactions*; Sage Publications: Newbury Park, CA, USA, 1991.
36. Wise, D.U.; Dunn, D.E.; Engelder, J.T.; Geiser, P.A.; Hatcher, R.D.; Kish, S.A.; Odom, A.L.; Schamel, S. Fault-related rocks: Suggestions for terminology. *Geology* **1984**, *12*, 391–394. [CrossRef]
37. Tanc, A.; Gokoglan, K. The impact of environmental accounting on strategic management accounting: A research on manufacturing companies. *Int. J. Econ. Financ. Issues* **2015**, *5*, 566–573.
38. Chen, C. *Robust Regression and Outlier Detection with the ROBUSTREG Procedure*; Paper 265-27; SAS Institute: Cary, NC, USA, 2002.
39. Stock, T.; Seliger, G. Opportunities of Sustainable Manufacturing in Industry 4.0. *Procedia CIRP* **2016**, *40*, 536–541. [CrossRef]
40. Bonilla, S.H.; Silva, H.R.; Terra da Silva, M.; Franco Gonçalves, R.; Sacomano, J.B. Industry 4.0 and Sustainability Implications: A Scenario-Based Analysis of the Impacts and Challenges. *Sustainability* **2018**, *10*, 3740. [CrossRef]
41. Dalenogare, L.S.; Benitez, G.B.; Ayala, N.F.; Frank, A.G. The expected contribution of Industry 4.0 technologies for industrial performance. *Int. J. Prod. Econ.* **2018**, *204*, 383–394. [CrossRef]
42. Przychodzen, J.; Przychodzen, W. Relationships between eco-innovation and financial performance-Evidence from publicly traded companies in Poland and Hungary. *J. Clean. Prod.* **2015**, *90*, 253–263. [CrossRef]
43. Schaltegger, S.; Hörisch, J.; Freeman, R.E. Business cases for sustainability: A stakeholder theory perspective. *Organ. Environ.* **2019**, *32*, 191–212. [CrossRef]
44. Hourneaux, F., Jr.; Gabriel, M.L.D.S.; Gallardo-Vázquez, D.A. Triple bottom line and sustainable performance measurement in industrial companies. *Rev. De Gestão* **2018**, *25*, 413–429. [CrossRef]