The Effect of AI Adoption and Green Leadership on Organizational Environmental Performance in SMEs

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Abstract

This study delves into the potential synergy between Artificial Intelligence (AI) adoption and green leadership within SMEs, responding to the growing environmental concerns and the imperative for technological advancement in the business landscape and assessing their combined impact on environmental performance. We conducted a survey involving 266 respondents in Bangladesh, employing Smart PLS-SEM for data analysis. The empirical results indicate a positive association between AI adoption and green investment, as well as environmental performance within SMEs. Furthermore, the research establishes that green leadership substantially influences an organization's green investment and environmental performance. Our study also demonstrated that green investment significantly improves environmental performance in SMEs. These findings help manufacturing managers integrate technology and human capital, mitigating environmental issues. Our study also provides SME managers and policymakers with a model for AI and green leadership implementation, enhancing green investment and overall performance.

Keywords: *AI Adoption, Environmental Performance, Green Leadership, Green Investment*

INTRODUCTION

The contemporary business landscape is marked by growing concerns regarding environmental sustainability and the imperative to adopt advanced technologies to remain competitive (Edwards, 2021; Singh et al., 2020; Tian et al., 2023). In this context, the adoption of AI has emerged as a transformative force, revolutionizing various aspects of organizational operations, and is widely regarded as one of the most innovative and ground breaking developments in recent times (Chen et al., 2022). Simultaneously, the necessity for sustainable green leadership practices has gained significant prominence, particularly among SMEs, which constitute a substantial share of the global business ecosystem (Singh et al., 2020; Sohns et al., 2023). Environmental sustainability has evolved from a peripheral concern to a central focus for organizations. Regulatory pressures, consumer preferences, and an increasing awareness of climate change have necessitated a reevaluation of business practices (Tian et al., 2023; Yan et al., 2021). SMEs, while being vital contributors to economic growth, also play a significant role in environmental impact due to their sheer numbers and diverse operations.

AI adoption (AIA) offers SMEs the potential to optimize their processes, reduce resource consumption, and enhance decision-making capabilities, all of which can significantly influence their environmental performance (Drydakis, 2022; Javaid et al., 2022; Mikalef & Gupta, 2021). Its applications are vast, from streamlining supply chains to automating customer service and predictive analytics. AI empowers SMEs to increase operational efficiencies, reduce costs, and secure competitive advantages in a fast-paced market (Haleem et al., 2022; Tian et al., 2023). Concurrently, green leadership entails financial commitments aimed at reducing an organization's environmental footprint. This leadership can take various forms, such as energy-efficient technologies, waste reduction initiatives, or eco-friendly supply chain practices (Singh et al., 2020; Sohns et al., 2023). While both AIA and green leadership independently promise environmental benefits, their interplay within SMEs remains an understudied area.

In emerging economies, comprehensive research on the association between AIA and the firms' environmental performance has been notably lacking. While numerous prior studies have examined the acceptance and

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utilization of technology by consumers (Chen et al., 2022; Tian et al., 2023), the literature concerning the impact of AIA on firms' environmental performance remains relatively scarce. Existing research on technology primarily delves into areas such as the influence of technology on a firm's financial performance (Shin, 2006), the adoption of renewable energy sources (Solarin et al., 2022), and access to credit (Moreira-Santos et al., 2022). Consequently, there hasn't been much investigation into how AI can improve a company's sustainability performance (Nishant et al., 2020; Pizzi et al., 2021), with a predominant focus on literature reviews and case studies. Moreover, the predominant focus of existing research has been on examining how technology influences organizational sustainability (Guang-Wen & Siddik, 2023; Liying & Ismail, 2023). However, (Pizzi et al., 2021) advocate for scholars to delve into the impact of AIA on firms' environmental performance through empirical analysis of primary data. The majority of the literature has centered its attention on scrutinizing the influence of various environmental and strategic factors on firms' environmental performance (Guang-Wen & Siddik, 2023), often overlooking the pivotal role played by technological drivers.

In recent years, the global discourse surrounding environmental sustainability has escalated to an unprecedented level of urgency and significance (Guang-Wen & Siddik, 2023; Tian et al., 2023; Yan & Zhang, 2021). This surge in concern is primarily driven by a confluence of factors, including alarming scientific evidence on climate change, the rapid reduction of finite natural resources, and the stark consequences of environmental degradation. These multifaceted challenges have propelled environmental sustainability to the forefront of global agendas and ignited a comprehensive reevaluation of how societies and organizations interact with the environment. Climate change, resource depletion, and environmental degradation have led to heightened awareness, stringent regulations, and increased consumer demand for eco-friendly products and responsible corporate behavior (Gu, 2022; Sohns et al., 2023; Yan et al., 2021). As part of this movement, organizations are turning their attention to green leadership, encompassing initiatives such as renewable energy adoption, waste reduction, sustainable sourcing, and carbon footprint reduction.

Even though both AIA and green leadership are becoming increasingly significant in the SME landscape and their respective impacts on environmental performance and innovation (Mikalef & Gupta, 2021; Tian et al., 2023), there exists a notable research gap. The intersection of these two domains and their combined influence on environmental outcomes remains relatively uncharted territory. Prior studies often tend to examine AI adoption or green leadership in isolation (Singh et al., 2020; Solarin et al., 2022; Yan et al., 2021), failing to capture the potential synergy or trade-offs between these strategies in the pursuit of environmental sustainability. Addressing this research gap is not only academically significant but also highly relevant for SMEs, which play a vital role in global economic development. Their ability to harness AI technologies and green leadership for improved environmental performance and innovation can have far-reaching implications for sustainability, competitiveness, and resilience.

This study aims to bridge this research gap by exploring how AI adoption and green leadership jointly influence organizational environmental performance, with green investment acting as a mediator. By delving into this multifaceted relationship, the research seeks to offer a complete understanding of how SMEs can effectively navigate the intersection of technological advancement and sustainability to improve their environmental performance. In our study, we draw upon the concepts of Ecological Modernization Theory (EMT) and the Ability-Motivation-Opportunity Theory (AMO) to provide a deeper understanding of how emerging technologies like AI and strategic resources such as green leadership facilitate firms' engagement in green investment, ultimately leading to improved environmental performance. The unexplored research gap within the framework of EMT theory and AMO theory was empirically examined by means of a survey involving 266 managers of SMEs from Bangladesh. The findings are expected to offer practical insights for SMEs aiming to align their growth objectives with environmental responsibility in an increasingly competitive and environmentally conscious business environment. Through rigorous empirical analysis, we aim to provide valuable insights that can inform SMEs, policymakers, and stakeholders on the path toward sustainable and innovative growth in an era characterized by the dual imperatives of technological advancement and environmental responsibility.

Background

While extant literature has delved into aspects such as consumer acceptance and sustained usage of technology (Ryu, 2018; Tian et al., 2023), scholarly attention directed toward comprehensively scrutinizing the ramifications of AI adoption on the environmental performance (ENP) of organizations remains notably limited. Existing research efforts have largely gravitated towards examining factors associated with consumer behavior and the adoption of AI, with a primary focus on aspects like user acceptance and the continued utilization of AI services (Bock et al., 2020; Chen et al., 2022; Tong et al., 2021; Wilson & Daugherty, 2018). However, the literature landscape exhibits a marked scarcity when it comes to comprehensive investigations into the complex relationship between AIA and the multifaceted realm of organizational ENP. Furthermore, research in the domain of green leadership has predominantly centered on examining the influence of internal factors on driving green innovation and ultimately influencing ENP within SMEs (Pizzi et al., 2021; Singh et al., 2020; Tian et al., 2023). However, scholars such as Ahmad et al. (2022) have urged empirical studies to extend their focus to encompass both internal and external factors contributing to SMEs' application of environmental strategies. This broader perspective is essential for a more comprehensive understanding of the processes involved in conceiving, implementing, and sustaining proactive environmental strategies. Additionally, Nishant et al. (2020) have claimed that the conjunction of technological adoption and managerial capabilities significantly enhances innovation and overall firm performance. Consequently, our research endeavors to scrutinize the influence of external AI factors, coupled with internal green leadership elements, on the ENP of manufacturing SMEs in Bangladesh.

SMEs in developing nations like Bangladesh often encounter significant financial hurdles, particularly when pursuing international expansion (Hassan et al., 2022; Khatun & Tamanna, 2021). This financial gap primarily results from a phenomenon known as information friction. SMEs have constraints in their financial resources and depend on external funding to support their expansion goals, yet they often encounter difficulties in obtaining trade credit (Siddik et al., 2023; Yan et al., 2021). Information imbalances between these SMEs and financial organizations play a pivotal role in these lending denials (Hassan et al., 2022). Therefore, it becomes evident that within the specific context of emerging economies, a substantial research void exists, warranting a more extensive exploration of the intricate dynamics between fintech adoption and the firms' environmental performance. This research gap emphasizes the need for further empirical investigations and scholarly inquiries into this critical domain.

The integration of environmental considerations into corporate strategies has been a subject of extensive exploration by experts across various fields. This endeavor has given rise to a multitude of theoretical paradigms, each offering unique insights into the incorporation of environmental concerns into business operations. These paradigms include ecological foot printing, the triple-bottom-line approach, ecology in industry, environmental efficacy, and life cycle management (Tian et al., 2023). While these conceptual models provide valuable frameworks for understanding environmental stewardship within organizations, they often highlight distinct facets of the same overarching concept. Consequently, it becomes apparent that environmental and socioeconomic stewardship can be considered by a myriad of theories rather than being exclusively governed by a single overarching theory (Tang et al., 2022; Tian et al., 2023). In the context of our research, we rely on two distinct theoretical frameworks to examine the influence of AIA and green leadership on firms' environmental performance. The ecological modernization theory (EMT) stands as a foundational pillar of our investigation. According to EMT, advancements in resource efficiency achieved through technical breakthroughs, such as AIA, have the potential to address environmental challenges stemming from economic growth and development (Tang et al., 2022).

As societies transition away from the old-industrial phase, they must undergo what is referred to as environmental modernization. Environmental modernization relies on contemporary methods, including a robust scientific knowledge base and cutting-edge technology, to enhance the Earth's carrying capacity and promote more sustainable growth (Huber, 2008). It strives to minimize raw material ingesting and pollution while fostering the development of innovative products (Andersen & Massa, 2000). Within the framework of EMT, we posit that advanced technologies like AI have the capacity to stimulate organizations' green investment endeavors, subsequently enhancing their environmental sustainability. By leveraging AIA,

organizations can optimize their resource utilization, reduce their environmental footprint, and develop environmentally conscious products and services. This aligns with the principles of ecological modernization and its emphasis on technological progress as a means to achieve greater sustainability. These theoretical foundations collectively inform our investigation into how AIA and green innovation can drive positive environmental outcomes within organizations.

Another pivotal theoretical perspective is the Affective, Motivational, and Opportunity (AMO) Theory, which focuses on the function of green investment in driving green human resource management practices and, subsequently, affecting employee motivation and skills. According to the AMO theory, green leadership fosters employee skill development and motivation, opening doors for environmental management initiatives (Haddock-Millar et al., 2016). Based on the AMO perspective, this study suggests that within organizations, green leadership seeks to attract, incentivize, elevate, and maintain employee conduct that aligns with environmental stewardship objectives and goals. These efforts are channeled through green leadership, ultimately contributing to superior environmental and corporate performance (Tian et al., 2023).

Hypotheses Development

AI Adoption (AIA) and Environmental Performance (ENP)

AI technologies, particularly machine learning and data analytics, empower firms to process and analyze vast datasets swiftly and accurately (Bock et al., 2020; Chen et al., 2022). Prior scholars argue that by efficiently managing resources such as energy, raw materials, and water, SMEs can significantly reduce waste and environmental impact (Guang-Wen & Siddik, 2023; Tian et al., 2023). For instance, AI-powered energy management systems can monitor and adjust energy usage in real-time, leading to reduced energy consumption and lower carbon emissions. AI can enhance SMEs' ability to monitor their environmental impact and ensure compliance with environmental regulations (Drydakis, 2022). Prior studies have claimed that AI-driven sensors and monitoring systems can continuously track emissions, pollutants, and other environmental indicators (Guang-Wen & Siddik, 2023; Javaid et al., 2022). AI-powered predictive maintenance systems can help SMEs extend the lifespan of their machinery and equipment. By detecting issues before they lead to breakdowns, SMEs can reduce the need for replacement parts and minimize the environmental footprint associated with manufacturing and disposal. By optimizing inventory management, transportation routes, and production schedules, SMEs can reduce unnecessary resource consumption and emissions associated with transportation and storage.

The argument aligns with the Ecological Modernization Theory (EMT) perspective, which suggests that improving resource efficiency through technological innovations, such as AI, can mitigate environmental challenges resulting from economic growth (Tang et al., 2022; Tian et al., 2023). AI, employing advanced data analysis and financial innovations, deals with current environmental sustainability issues such as circular procurements, recycling, resource conservation, renewable energy use, and the reduction of carbon emissions (Guang-Wen & Siddik, 2023; Tian et al., 2023). This immediate impact of AI on corporations can efficiently reduce financial constraints faced by businesses operating in high-pollution industries (Sohns et al., 2023). In sum, the AIA in SMEs offers a myriad of opportunities to enhance ENP. By leveraging AI's capabilities in resource optimization, monitoring, innovation, and decision support, SMEs can reduce their ecological footprint, comply with environmental regulations, and gain a competitive advantage. Therefore, there is a strong rationale to believe that AIA positively influences SMEs' ENP, aligning with hypothesis H1.

H1: AI Adoption Positively Affects Firms' Environmental Performance.

AI Adoption (AIA) and Green Investment (GI)

Green investment refers to the practice of investing capital in businesses, projects, or financial instruments that have positive environmental and social impacts in addition to generating financial returns (Guang-Wen & Siddik, 2023). Environmentally conscious businesses leveraging green resources have demonstrated significant success in promptly meeting consumer demands (Singh et al., 2020; Tian et al., 2023). Prior research has established a substantial link between technology adoption and the facilitation of GI (Guang-Wen & Siddik,

2023; Rao et al., 2022). However, the presence of considerable information asymmetry has discouraged firms from extending financing to businesses for their green investment initiatives (Sohns et al., 2023). To remain competitive, firms are undergoing transformations within the sector, aiming to enhance their screening processes and reduce mismatches of resources that are ineffective or geared toward lower-end ventures (Haddock-Millar et al., 2016). The AIA contributes to increased transparency in businesses and enhances stakeholders' ability to investigate information through technologies (Rao et al., 2022). This, in turn, advances the efficiency of capital flow within businesses and directs funds toward green investment. As a result, AI enhances the beneficial ripple effect of green investment by encouraging cooperation among companies and stakeholders (Guang-Wen & Siddik, 2023).

AI may further stimulate green investment by driving investments in research and development (R&D). Previous studies have directed that heightened R&D spending in the context of environmental innovation can impact green investment (Haddock-Millar et al., 2016). An increase in R&D expenditures encourages businesses to procure new green technology equipment, encompassing software and hardware infrastructure while phasing out older equipment (Guang-Wen & Siddik, 2023). The availability of AI services significantly encourages businesses to adopt green control technology, as it enhances both financing options and social trust (Rao et al., 2022; Sohns et al., 2023). Consequently, AI serves as a substantial catalyst for regional GI (Rao et al., 2022). Through the utilization of AI features, green systems and products can be developed, enabling recycling, reuse, and circular production. Therefore, we propose the following hypothesis:

H2: AI adoption positively affects firms' green investment.

Green Leadership (GL) and Environmental Performance (ENP)

Green leadership encompasses a leadership approach that prioritizes environmental sustainability within the organization (Tian et al., 2023). It involves leaders who are committed to and actively engage in fostering environmentally responsible behaviors and practices among their employees and throughout the company (Guang-Wen & Siddik, 2023; Tong et al., 2022). GL, characterized by transformational leaders who model sustainable behaviors, create a culture of environmental responsibility, and adapt leadership practices to the ecological context, is suggested to have a favorable impact on firms' ENP. Through their visionary guidance and commitment to sustainability, green leaders inspire employees to embrace and implement environmentally friendly practices, leading to reduced environmental impact and enhanced ENP within the organization (Singh et al., 2020; Yan et al., 2021).

Prior studies have established that the promotion of GL aligns with the increasing societal and regulatory pressure on firms to adopt sustainable practices and reduce their environmental footprint (Singh et al., 2020; Tian et al., 2023). As such, it is expected that organizations with green leaders will exhibit superior ENP by proactively addressing environmental challenges, minimizing resource consumption, and contributing to broader environmental sustainability goals. The argument aligns with the AMO theory perspective, which suggests the role of GL in driving green HRM practices and, subsequently, affecting employee motivation and skills. According to the AMO theory, GL boosts employees' abilities and drive, opening doors for initiatives in environmental management (Tian et al., 2023). Thus, we propose the following hypothesis:

H3: Green leadership positively affects firms' environmental performance

Green Leadership (GL) and Green Investment (GI)

Green leadership is expected to positively affect green investment within organizations due to the pivotal role of leadership in shaping strategic decisions and resource allocation (Guang-Wen & Siddik, 2023; Tian et al., 2023). Green leaders, through their commitment to sustainability and their ability to inspire and motivate others, create an organizational culture that values and prioritizes environmentally responsible practices (Tong et al., 2022). This cultural shift extends to investment decisions, prompting organizations to allocate resources toward green initiatives (Singh et al., 2020). Empirical evidence supports this hypothesis, with studies demonstrating that organizations led by environmentally conscious leaders are more likely to be involved in GI practices (Singh et al., 2020; Tian et al., 2023). Green leaders' values and beliefs align with a strategic orientation toward

sustainability, leading to a greater readiness to invest in eco-friendly technologies, energy-efficient processes, and sustainable practices (Guang-Wen & Siddik, 2023).

Furthermore, GI is gradually recognized as a source of competitive advantage and long-term profitability (Guang-Wen & Siddik, 2023). Organizations that strategically invest in sustainability often reap benefits in the form of cost savings reduced environmental risks, and enhanced corporate reputation (Singh et al., 2020). Green leaders are attuned to these advantages and are more likely to champion green investment as a means to achieve both environmental and strategic objectives. Therefore, we propose the following hypothesis:

H4: Green leadership positively affects green investment

Green Investment (GI) and Environmental Performance (ENP)

Recent global environmental concerns, driven by climate change, resource depletion, and environmental degradation, prompt businesses to adopt sustainable practices (Tang et al., 2022). GI, in this context, refers to capital allocated for activities aimed at reducing environmental impact, improving resource efficiency, and promoting sustainable business practices (Singh et al., 2020; Tong et al., 2022). Several studies have highlighted the positive relationship between GI and ENP (Tian et al., 2023; Yan et al., 2021). GI encompasses initiatives like renewable energy adoption, waste reduction, sustainable sourcing, and carbon footprint reduction, all of which contribute to improved environmental sustainability (Guang-Wen & Siddik, 2023; Pizzi et al., 2021). These investments enable firms to reduce resource consumption, lower emissions, and adopt eco-friendly technologies, ultimately resulting in enhanced ENP.

GI, guided by the principles of EMT, seeks to enhance resource efficiency through technological innovations (Tang et al., 2022; Tian et al., 2023). EMT contends that adopting advanced technologies and sustainable practices can mitigate environmental challenges arising from economic growth (Huber, 2008). GI aligns with the core tenets of EMT by fostering resource conservation, sustainable production, and reduced environmental impact (Tian et al., 2023). Firms that invest in environmentally friendly practices often experience improvements in their financial performance. GI can lead to cost reductions through more efficient resource utilization and waste management (Guang-Wen & Siddik, 2023). We argue a positive relationship between GI and firms' ENP is grounded in theoretical perspectives like ecological modernization theory and supported by empirical evidence. GI is not only a response to environmental concerns but also a strategic choice that enables firms to improve their resource efficiency, reduce their environmental footprint, and align with regulatory requirements and stakeholder expectations. As we proceed with our research, we will explore this relationship further, considering the multifaceted dimensions of GI and its impact on firms' ENP.

H5: Green investment positively affects firms' environmental performance

The Mediating Role of Green Investment

AIA represents the integration of cutting-edge technology into organizational processes, enabling improved decision-making, enhanced efficiency, and reduced resource consumption (Chen et al., 2022). This technology is increasingly recognized for its potential to drive environmental sustainability by optimizing resource allocation and reducing waste (Tang et al., 2022). Conversely, GI entails allocating financial resources towards eco-friendly initiatives, such as renewable energy, sustainable supply chains, and environmentally responsible production processes (Guang-Wen & Siddik, 2023). These investments are designed to enhance an organization's ENP by reducing its ecological footprint and mitigating adverse environmental impacts (Singh et al., 2020). Empirical studies have consistently confirmed the interconnectedness of technology adoption, GI, and ENP within organizations. For instance, Tian et al. (2023) conducted research on manufacturing firms and found that technology adoption positively influenced green investment. Their findings indicated that organizations embracing AI technologies were more likely to allocate resources towards environmentally responsible initiatives. AIA has the potential to enhance ENP, but this relationship is strengthened and realized through the mediating effect of green investment. As organizations invest in green initiatives, they are better positioned to leverage AI technologies for more sustainable and environmentally responsible operations, ultimately leading to improved ENP. There, we propose the following mediating hypothesis:

H6: Green investment mediates the relationship between AI adoption and environmental performance.

Green leadership involves individuals who champion sustainability, possess a deep commitment to environmental stewardship, and actively promote green initiatives (Tian et al., 2023). Such leaders shape an organization's culture, values, and strategic orientation toward sustainability (Guang-Wen & Siddik, 2023; Tong et al., 2022). Their findings showed that leaders' are more inclined to advocate for environmentally responsible practices, which can significantly influence the allocation of resources toward green investments. Green investment encompasses the allocation of financial resources to eco-friendly projects and initiatives, aiming to reduce an organization's environmental impact (Singh et al., 2020). This can include investments in energy-efficient technologies, renewable energy sources, sustainable supply chains, and waste-reduction strategies (Guang-Wen & Siddik, 2023). Empirical studies support the premise that green leadership positively influences green investment practices within organizations. Research by Tian et al. (2021) found that firms with environmentally conscious leaders were more likely to invest in sustainable technologies and practices. Moreover, green investment has been consistently linked to improved environmental performance (Guang-Wen & Siddik, 2023). Investments in eco-friendly initiatives can lead to reduced resource consumption, lower emissions, and more sustainable operations, contributing to enhanced environmental performance (Tang et al., 2022). We argue that green leaders' commitment to sustainability encourages greater investment in environmentally responsible practices and technologies, ultimately leading to improved environmental performance within organizations. Thus, we propose the following mediating hypothesis:

H7: Green investment mediates the relationship between green leadership and environmental performance
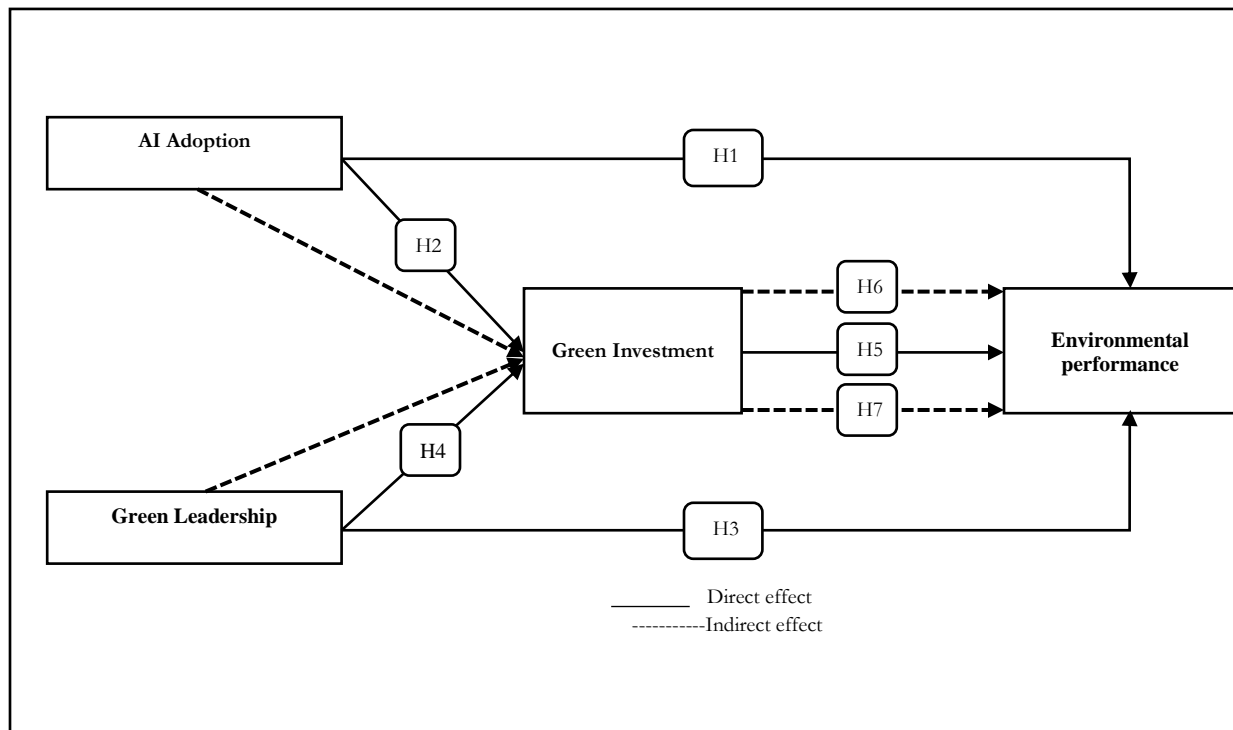

Figure 1. Research framework

RESEARCH METHODS

Sampling and data collection

The researchers conducted a survey among SMEs in Bangladesh to assess the proposed hypotheses. These chosen SMEs operate within a competitive landscape where strategic tactics like embracing technology and demonstrating dynamic leadership play a pivotal role in enhancing investment and performance. Data were

gathered from the largest regions in Bangladesh, namely Dhaka and Chittagong. These two areas collectively account for 53% of the entire SME population in Bangladesh, with Dhaka constituting 38% and Chittagong 15% (Tian et al., 2023). Moreover, Bangladesh was selected as the location for the empirical investigation for several compelling reasons. To begin with, SMEs play a vital role in the Bangladeshi economy, providing direct employment to 7.8 million individuals and supporting an additional 31.2 million (The World Bank, 2019). These SMEs contribute to approximately 25% of the country's GDP and have the potential to make even more substantial contributions (Tian et al., 2023).

Being an emerging economy, Bangladesh is also actively working towards achieving the United Nations' Sustainable Development Goals (Guang-Wen & Siddik, 2023; Tian et al., 2023). This commitment has led to the emergence of numerous businesses, particularly SMEs. However, it's important to note that vulnerable SMEs in Bangladesh faced considerable challenges during the COVID-19 pandemic (Guang-Wen & Siddik, 2023). Many businesses were forced to shut down temporarily, while others experienced significant financial losses. Examining the strategies through which Bangladeshi SMEs can integrate AI technologies and sustainable business approaches to ensure a thriving business environment, both domestically and internationally, holds significant importance. Additionally, it's noteworthy that many Bangladeshi SMEs have historically shown reluctance in embracing eco-friendly measures and adhering to environmental guidelines. Nevertheless, this scenario is gradually evolving, partly due to international organizations providing financial support to incentivize SMEs to align with environmental standards. Numerous global development agencies have invested in initiatives related to worker safety, the adoption of eco-conscious manufacturing methods, and environmental considerations within Bangladesh's extensive garment manufacturing sector.

The Sustainable Enterprise Project, a World Bank initiative, is actively supporting 40,000 SMEs in Bangladesh (Tian et al., 2023). Its primary aim is to facilitate the implementation of environmentally friendly growth strategies among these enterprises. This includes the diversification of their business portfolios to encompass various aspects of environmental stewardship, such as the management of waste and emissions, as well as the enhancement of workplace safety standards. These SMEs are consistently integrating the latest technological advancements into their operations, as reported by The Financial Express (2022). Consequently, it is imperative to investigate how the AIA and the development of green leadership can contribute to the advancement of green innovation and overall performance among manufacturing firms in Bangladesh.

We created a self-administered questionnaire to gather data concerning the impact of AI adoption and green leadership on the environmental performance of SMEs in Bangladesh. Prior to the main survey, a validation process was undertaken involving two academic experts and ten managers from manufacturing SMEs who assessed the survey questionnaires for accuracy and appropriateness. Based on the outcomes of the pilot survey, the researchers made slight adjustments to the questionnaire items. The data for the survey were gathered from managers of SMEs who possessed a minimum of three years of experience in managing their companies' operations. A total of 600 SME managers received the survey, accompanied by a cover letter outlining the study's objectives and underlining the voluntary nature of participation. Additionally, participants were assured that their responses would remain confidential and solely used for academic research purposes. Following this, 266 surveys were returned in a complete and valid state, yielding a response rate of 44.33%. Data collection for this research spanned from May 2023 to August 2023. Among the respondents, 83.6% were male, while 16.4% were female. The majority of managers (79%) fell in the age bracket of 25 to 50 and held at least a postsecondary degree (73%). In terms of business focus, 49% of firms provided services directly to individual customers, 23% served other businesses directly, and 28% served both customers and enterprises directly. The study encompassed four categories based on the age of the firms: 3 years (12%), 3 to 5 years (28%), 6 to 10 years (42%), and over 10 years (18%). In addition to these characteristics, 65% of the enterprises employed fewer than 50 workers, 27% had workforces ranging from 51 to 100 employees, and 8% had more than 100 employees.

Measurement Items

In the course of our literature review, we identified scales that could be employed to measure the variables incorporated in our research. For data collection concerning the potential influence of AI adoption and green

leadership on environmental performance, we employed structured questionnaires. These questionnaires were adapted from existing studies in the field. The structured questionnaire comprises two main sections: the initial section is dedicated to collecting demographic information from the respondents, while the second section encompasses questions related to both the endogenous and exogenous factors that are central to our study. Respondents provided their answers using a seven-point Likert rating scale, where a rating of 1 signifies "strongly disagree," and a rating of 7 indicates "strongly agree." This scale allowed us to capture the nuances of their responses and gauge their levels of agreement or disagreement with the questionnaire statements. To evaluate the level of AI adoption, we used a set of seven items derived and adapted from prior research studies (Tian et al., 2023; Yan et al., 2021). Green managerial leadership was assessed through a scale comprising six items, adapted and refined from Tian et al.,'s (2023) research. To evaluate the Green Investment construct, we utilized a set of six items sourced from the research (Guang-Wen & Siddik, 2023). Lastly, Environmental Performance (ENP) was gauged through a scale comprising five items, which were adapted from the research conducted by Guang-Wen & Siddik (2023) and Tian et al. (2023). Additional information regarding the measurement items can be found in the Appendix..

Data Analysis and Results

This study employed Partial Least Squares Structural Equation Modeling (PLS-SEM) using Smart PLS version 4 software to test the proposed hypotheses. The analysis consisted of two parts: a measurement model evaluation and a structural model examination. Assessing the measurement model's reliability, validity, and measurement model fit allowed for its evaluation. The structural model was evaluated by examining the path coefficients and their levels of statistical significance levels.

Common Method Bias

To address the potential impact of common method bias on the hypothesized relationships within the PLS path model, two approaches were employed. The first method involved utilizing Harman (1976) single-factor test, whereby the first factor retrieved through principal axis factoring without rotation explained only 14.49% of the total variance. Since this proportion is less than the indicated 50% threshold value (Podsakoff & Organ, 1986), common technique bias is not likely to have significantly impacted the results. According to Kock (2015), we performed a comprehensive collinearity analysis and discovered that the greatest VIF was 2.67, which is below the suggested cutoff of 3.3 provided by Kock and Lynn (2012).

Measurement Model Assessment

Internal consistency was examined using Cronbach's alpha (CA) and composite reliability (CR) to determine the reliability of the measures. All constructs exhibited acceptable levels of internal consistency, with CA ranging from 0.71 to 0.88 and CR ranging from 0.84 to 0.91. Convergent and discriminant validity were used to evaluate the instruments' validity. Convergent validity was examined by analyzing the factor loadings, average variance extracted (AVE), and CR. The factor loadings were all above 0.7, and the AVE ranged from 0.67 to 0.76, suggesting good convergent validity. Fornell-Larcker criteria and the HTMT of correlations were used to evaluate discriminant validity. The results indicated that all constructs had discriminant validity.

Table 1. Measurement Model

Latent Variable	Items	Loadings	CA	CR	AVE
Environmental Performance	ENP1	0.78	0.713	0.844	0.672
	ENP2	0.84			
	ENP3	0.75			
	ENP4	0.79			
	ENP5	0.81			
AI adoption	AIA1	0.86	0.822	0.913	0.765
	AIA2	0.87			
	AIA3	0.88			
	AIA4	0.78			
	AIA5	0.89			
	AIA6	0.90			
	AIA7	0.79			
Green leadership	GL1	0.91	0.882	0.879	0.764
	GL2	0.93			
	GL3	0.74			
	GL4	0.88			
	GL5	0.82			
	GL6	0.88			
Green Investment	GI1	0.78	0.760	0.874	0.694
	GI2	0.87			
	GI3	0.76			
	GI4	0.77			
	GI5	0.81			
	GI6	0.82			

Table 2. Correlation matrix and square root of the AVE

Constructs	AIA	GL	GI	ENP
AIA	0.729			
GL	0.535	0.869		
GI	0.387	0.592	0.874	
ENP	0.517	0.464	0.665	0.845

Table 3. Heterotrait-monotrait ratio (HTMT)

Constructs	AIA	GL	GI	ENP
AIA				
GL	0.455			
GI	0.397	0.563		
ENP	0.561	0.799	0.688	

Structural Model Assessment

The structural model was evaluated in line with Hair et al. (2017) guidelines by examining the explained variance (R^2), the magnitude and significance of path coefficients, and the predictive relevance of endogenous constructs (Q^2). As depicted in Table 4, our model demonstrated an appropriate predictive power level for several dependent variables. The R-squared values for the endogenous constructs were 0.328 for green investment and 0.412 for environmental performance. These values indicate that the proposed variables explained a significant proportion of the variance in the endogenous constructs. These results were further supported by the Stone-Geisser (Q^2) tests, which were computed using the blindfolding method and revealed non-negative values greater than zero for all endogenous constructs, indicating the model's predictive capabilities (Hair et al., 2016). We calculated t-values and significance levels using the bootstrapping method with 5000 subsamples for testing the hypotheses (Hair et al., 2016), as shown in Table 4.

Table 4. Structural Model Assessment

Path	β	t-value	p-value	Hypothesis
AIA -> ENP	0.228	5.744	000	Supported
AIA -> GI	0.426	7.193	000	Supported
GL -> ENP	0.292	3.827	000	Supported
GL-> GI	0.238	2.998	000	Supported
AIA -> GI-> ENP	0.366	5.409	000	Supported
GL -> GI-> ENP	0.301	4.793	000	Supported

DISCUSSION AND CONCLUSION

Discussion

In our investigation, we examined how AI adoption and green leadership influence the environmental performance of firms by promoting increased green investment. We conducted this research by drawing upon the EMT and the AMO theories. Empirically, we explored the connections between several key factors: AI adoption and green investment, AI adoption and environmental performance, green leadership and green investment, and green leadership and environmental performance. Additionally, we delved into the potential mediating role played by the green investment of firms within these relationships. The research posited a hypothesis (H1) asserting that the adoption of AI has a positive influence on the ENP of SMEs in Bangladesh. The outcomes of the PLS-SEM analysis confirm the validation of Hypothesis 1. This proposition aligns with previous findings in the literature concerning the adoption of technology and its impact on environmental sustainability, as evidenced by studies such as those by Pizzi et al. (2021) and Tian et al. (2023). Furthermore, scholars in the field of environmental studies have illustrated that technological advancements facilitate the creation of green financial mechanisms, including eco-friendly loans and investments. These mechanisms, in turn, foster environmental sustainability and the growth of sustainable practices (Sohns et al., 2023). Moreover, this research broadens the perspective of EMT by proposing that improving resource efficacy through technological advancements, such as AI, can effectively tackle environmental issues stemming from economic expansion (Tang et al., 2022; Tian et al., 2023).

As hypothesized in H2, the adoption of AI has a positive influence on firms' engagement in green investment activities. This outcome aligns with prior studies that have claimed the impact of technology on augmenting firms' green investment practices (Guang-Wen & Siddik, 2023; Rao et al., 2022; Sohns et al., 2023). Existing literature has consistently demonstrated that technology enhances the efficiency of corporate capital flows, directing funds toward new green investment initiatives (Guang-Wen & Siddik, 2023). Moreover, the swift infusion of resources fosters collaboration between firms and stakeholders, amplifying the positive effect of green investment (Sohns et al., 2023). This heightened collaboration also facilitates the assimilation of crucial knowledge concerning green investment within businesses. Our results validate the EMT proposition, offering empirical proof of how technological innovations improve firms' performance in the context of green or environmental innovation (Tian et al., 2023).

We observe that green leadership plays a pivotal role in predicting the environmental performance of firms (H3). This discovery is in harmony with the body of literature that has consistently demonstrated a positive association between green leadership and the ENP of firms (Guang-Wen & Siddik, 2023; Tian et al., 2023).

Green leadership bolsters the green capabilities, commitment, and potential of businesses, ultimately leading to improved ENP (Singh et al., 2020). Recent empirical research has further underscored the role of green leadership in facilitating organization-wide Green HRM practices, which, in turn, enhance the ENP of SMEs (Tang et al., 2022). Additionally, this finding lends support to the perspective of the AMO framework, suggesting that organizations can effectively address environmental challenges through the exercise of green leadership. Furthermore, the function of green leadership in influencing green investment, as posited in H4, is of paramount importance. Existing literature has consistently substantiated the significant impact of green leadership on green investment. For instance, prior studies found green leadership promotes investment in electronics and green creativity in tourism (Singh et al., 2020; Tong et al., 2022). Recent studies apply AMO theory, emphasizing green leadership's role in enhancing investment (Haddock-Millar et al., 2016; Tian et al., 2023).

Moreover, the PLS-SEM analysis reveals that green investment emerges as the most influential predictor of firms' environmental performance. This finding is consistent with a multitude of previous research that has emphasized the crucial function of green investment in improving firms' ENP (Guang-Wen & Siddik, 2023; Pizzi et al., 2021; Tang et al., 2022). Environmental scholars argue that green investment serves as a vital strategic driver for sustainable development. It encompasses technological innovations targeting energy efficiency, pollution mitigation, and resource optimization (Tian et al., 2023). Green investment has the potential to decrease pollution, toxic waste generation, and waste management expenses while ensuring compliance with outside environmental regulations and stakeholders' concerns (Guang-Wen & Siddik, 2023).

Finally, the relationship between AI adoption and firms' ENP is mediated by corporate GI. The mediation analysis reveals that AI adoption positively influences GI, subsequently leading to improvements in ENP. This mediating role of GI in connecting technology adoption with firms' environmental sustainability performance has likewise been documented in contemporary investigations (Guang-Wen & Siddik, 2023; Yan et al., 2021). For instance, Guang-Wen and Siddik (2023) found that AI adoption's impact on firms' ENP can be partially explained by its effect on GI. Furthermore, green leadership plays a pivotal role in driving GI and, consequently, firms' ENP in the manufacturing sector. Some studies have demonstrated the mediating role of GI in the relationship between green leadership and ENP (Singh et al., 2020; Tong et al., 2022) and have affirmed that GI indeed mediates this association. Similarly, Singh et al. (2020) provide additional support for our argument by demonstrating that the green leadership of top management influences SMEs' green product and process innovation, ultimately contributing to improved ENP. It's noteworthy that this study corroborates these findings in a distinct economic and industrial context. Therefore, this research is among the first to empirically verify how GI influences firms' ENP through AI adoption.

Theoretical Implications

This research contributes significantly to the theoretical landscape in two fundamental ways: by extending the applicability of the EMT and AMO theories. EMT suggests that integrating new and comprehensive technologies can ameliorate the environmental impact of business operations. Our study offers empirical evidence supporting the notion that the adoption of AI technology can enhance green investment and subsequently improve the environmental performance of businesses. Moreover, in line with the AMO theory, we offer empirical substantiation that green leadership augments the capabilities, motivation, and opportunities available to employees, thereby catalyzing green investment and enhancing the overall environmental performance of corporations.

Our study adds significantly to the foundation of future research in the realm of environmental management, particularly investigations into the interplay of AI adoption, green leadership, green investment, and organizational environmental performance in the manufacturing sector. This conceptual framework is founded on the intricate relationships among AI adoption, green leadership, green investment, and the environmental performance of organizations. Importantly, our research offers empirical validation for the indirect effects of AI adoption and green leadership on the enhancement of organizational environmental performance, elucidating the mediating role played by green investment in these connections.

Our work extends the literature on green innovation by shedding light on the mediating function of green investment in the nexus between AI adoption, green leadership, and environmental performance. Previous research predominantly treated green investment as either a consequence of technology adoption or a facilitator of organizational ENP, neglecting its intermediary role. Our study squarely focuses on the mediating role of green investment in the relationships between AIA and ENP, as well as green leadership and environmental performance. The empirical evidence underscores that green investment serves as a positive mediator in both the AI adoption−environmental performance and green leadership−environmental performance linkages. Consequently, these findings suggest that the AIA and the cultivation of green leadership capabilities empower manufacturing SMEs to engage in green product and process innovation, thereby potentially amplifying their environmental performance. By addressing the significant yet underexplored mediating role of green investment in AI adoption−environmental performance and green leadership−environmental performance associations, our research enriches the existing body of knowledge in this domain.

This study adds to the existing body of knowledge concerning AI and green leadership, particularly within the context of emerging economies, as exemplified by Bangladesh. It is crucial to highlight that research on AI and green leadership in emerging regions remains limited. This gap in the literature has been a motivating factor for our study, which seeks to investigate the AIA and the cultivation of green leadership in the specific context of Bangladesh. Furthermore, our research delves into the role of green investment and its mediating effects in this context. It's worth noting that there is a notable scarcity of empirical evidence in the setting of manufacturing SMEs, which amplifies the significance of our study in the context of existing research. Consequently, our research serves to not only expand but also enrich the exploration of AI, green leadership, green investment, and their collective impact on environmental performance within the manufacturing SME industry in Bangladesh.

Policy and Managerial Implications

This study carries significant policy implications for both governmental bodies and organizations alike. Firstly, it underscores the importance of tailoring laws and regulations to the specific context of each country, with particular importance on the localization of AI and green investment practices. Given that the readiness and capacity of individual countries to embrace and implement AI and green investment practices can differ significantly, it is imperative for national governments to gain a comprehensive understanding of these concepts. They must then align these concepts with their national and local economic objectives. By establishing clear directions and guidelines that take into account the unique circumstances of each country, regulatory frameworks can be developed and implemented with greater flexibility. This, in turn, enhances the prospects of successful AI adoption within the SME sector while also contributing to the achievement of the nation's sustainability goals.

Secondly, to harness the benefits of technological innovation for mitigating adverse environmental impacts, it is imperative for the government to prioritize the acceptance and active involvement of all relevant stakeholders in the adoption of technology and green investment practices. Given its status as an emerging economy, Bangladesh should formulate national policies geared towards the adoption of AI and green investment. These policies should be further reinforced through the enactment of legislation designed to incentivize their implementation. Businesses, particularly manufacturing SMEs, play a crucial role in the AIA and green investment, as they bear the responsibility of integrating and advancing innovations while aligning their business models with the government's objectives. Firms should place a strong emphasis on aligning their innovative efforts and industrial strategies with the goals and initiatives of various stakeholders. Consequently, through effective government-industry interactions, the technological advancements and structural transformations driven by AI technologies and green investments can have a favorable impact on sustainable development.

Furthermore, managers of manufacturing SMEs in emerging economies should prioritize the cultivation of green leadership qualities. These leaders play a critical role in motivating their staff to achieve environmental objectives and encouraging them to surpass conventional ecological standards. SME managers must inspire their employees to obtain, share, and apply the expertise and technological competencies necessary for the implementation of green investments, thereby enhancing the environmental performance of their businesses.

CONCLUSION

This study investigates the impact of AIA and green leadership on the ENP of Bangladeshi manufacturing SMEs. Our findings indicate that both AI adoption and green leadership have a positive influence on the environmental performance of these enterprises. AI technologies offer versatile solutions to address ecological challenges, especially in industries with elevated pollution levels. AI adoption paves the way for green investment mechanisms, such as green loans, fostering green growth and ecological sustainability. Moreover, the presence of green leaders within these organizations serves as a driving force behind environmentally friendly work practices, significantly contributing to improved environmental performance. Notably, our study reveals the crucial role of green investment as a mediator in the relationship between AI adoption, green leadership, and environmental performance. AI adoption provides greater access to financial resources, facilitating investments in green products and processes that, in turn, enhance environmental performance. Green leadership acts as an enabler for increased green investment, further amplifying positive environmental outcomes.

This study, while providing valuable insights, has its limitations and opens avenues for further investigation. It offers initial evidence, which should serve as a foundation for future research examining the relationship between AIA, green leadership, green investment, and organizational ENP. Subsequent studies should delve into the various facets of GI, encompassing product, process, and managerial innovations. While this research attempts to encompass the potential impacts of AI and GL, further exploration is essential to gain a comprehensive understanding of the diverse dimensions of financial technology and green leadership.

Moreover, this study predominantly concentrates on SMEs in Bangladeshi manufacturing. However, firms in different emerging markets and sectors may exhibit distinct adoption trends and technological proficiencies, warranting investigation. Comparative global studies could extend the applicability of these findings. This study, one of the few empirically exploring the link between firm-level AIA and SMEs' ENP, calls for additional empirical examinations of the consequences of AIA on corporate environmental conduct and sustainability performance. Lastly, due to the utilization of a cross-sectional research design, this study lacks insights into longitudinal connections among the investigated constructs. Subsequent research should utilize longitudinal studies to evaluate the long-term impacts of Fintech and GL on GI and firms' ENP, thereby enhancing our comprehension of these intricate relationships

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