

Article

Leveraging Digitalization to Boost ESG Performance in Different Business Contexts

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Abstract

Digital technology has become an essential engine of green development and economic progress due to the meteoric rise of new technologies. Our paper seeks to explore the impact of digitalization on environmental, social and governance (ESG) performance in different business contexts. Data were collected from listed firms across 19 Asian countries from 2015 to 2024, covering 1839 firms, yielding 18,390 firm-year observations and establishing a balanced panel data set. We used the dynamic panel data model to test the proposed hypotheses. The findings revealed that digitalization has a significant and positive impact on ESG performance. It also revealed that environmental uncertainty moderates this relationship. Moreover, our analysis indicated that the impact of digitalization on ESG performance is stronger for product (vs. service) firms, stronger for B2B (vs. B2C) firms and stronger for firms in IT-intensive industries. In addition, the analysis indicated that the impact of digitalization on ESG performance is stronger in more dynamic, complex and munificent environments. Our examination offers meaningful implications for theory and practice by expanding our knowledge of the complex mechanism underpinning the positive correlation between digitalization and ESG performance.

Keywords: digitalization; ESG performance; B2B vs. B2C; product vs. service; environmental uncertainty



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1. Introduction

The integration of digitization within companies emerged as a catalyst to improve environmental, social and governance benefits (ESG) [1]. The intersection of technological progress and corporate strategies has led to a movement of the paradigm in the way the organizations approach ESG metrics, particularly in terms of monitoring, reporting and operational efficiency [2]. Recent empirical studies accentuate this transformation. For example, a prior study examines how the adoption of advanced data analysis technologies and the Internet of Things (IoT) allows companies to collect environmental data in real time,

facilitating a more informed decision-making process and efficient resource management [3]. The results of that study confirm the statement that companies that exploit digital tools can improve their environmental performance by optimizing energy consumption and minimizing waste, with a consequent measurable improvement in ESG results.

As companies are increasingly committed to digital technologies, the interrelation between digitalization and ESG performance becomes more pronounced. Digital tools facilitate innovative solutions that face ESG challenges, allowing an improvement in operational efficiency, the involvement of the community and improved sustainability practices [4,5]. The literature corpus indicates a clear trajectory in which technological progress acts as a fundamental factor for companies that aim to raise their commitment to ESG principles, ultimately remodeling the company landscape in an era defined by digital transformation. The intersection between digitization and social factors in environmental, social and governance (ESG) management is increasingly recognized as critical for companies aimed at implementing responsible operational practices. The integration of digital technologies has been shown to considerably improve the commitment of stakeholders, which is a vital component of social performance in ESG assessments. Previous studies show how digital tools, such as social media platforms and collaborative technologies, promote real-time communication between organizations and their stakeholders [6]. This improved transparency can lead to an improvement in confidence and the management of reputation, which are essential dimensions of social responsibility [7,8].

Digitization is increasingly becoming a cornerstone of sustainable performance in the retail sector, presenting transformative opportunities in various dimensions, including supply chain efficiency, consumer behavior and environmental impact [9]. The integration of digital technologies has revolutionized traditional operational structures, promoting greater transparency, response capacity and efficiency. Such developments not only drive competitive advantage, but also align with sustainability goals [10,11]. The improvement of supply chain efficiency is notably associated with the implementation of Industry 4.0 technologies. A prior study states that technologies such as the Internet of Things (IoT), big data analytics and artificial intelligence facilitate enhanced decision making and resource management in supply chains [12]. These technologies contribute significantly to the performance of the sustainable supply chain through the mediation of practices and principles of the green supply chain of the circular economy [1]. As digital structures are adopted, organizations can reduce waste, reduce carbon footprints and optimize logistics operations, resulting in economic and environmental benefits.

Increased sustainable performance in the retail sector through digitization is a multifaceted phenomenon. By improving supply chain efficiency, transforming consumer behavior and reducing environmental impact, digitization equips retailers with the tools needed to thrive into an increasingly competitive and conscious market for ecologically conscious [13,14]. Future research should deepen the identification of specific strategies that facilitate digital transition, emphasizing sustainable practices to ensure the longevity and relevance of the retail industry in its efforts to achieve sustainable development goals. While underlined by prior examination, a different understanding of digitization resources will equate retail stakeholders to promote a sustainable future, thus aligning economic growth with environmental administration [15,16].

Research specifically investigating whether digitalization might enhance organizations' ESG performance is limited, despite the fact that prior examinations have focused on the link between digitalization and responsible initiatives of companies. The exception to this rule is a prior study that looked at Chinese listed firms from 2012 to 2020 and concluded that digitalization greatly enhances ESG rankings [17]. There are two pathways that they pinpoint as ways in which digitalization impacts ESG performance. To begin, businesses

can improve their governance (G) scores and decrease agency costs through digitization. Second, businesses are able to boost their social (S) scores and general goodwill with the help of digitization. Curiously, they failed to discover that digitization enhances environmental (E) scores for corporations. However, there may be subtle ways in which digitalization impacts environmental scores; for instance, the impact of digitalization on ESG performance may be greater for products than for services. Moreover, companies' use of "business-to-business (B2B) or business-to-consumer (B2C) channels" to compete is another key contextual variance in the marketing literature. The possible relevance of the stronger organizational alignment and adaptation between sellers and buyers in a B2B context to digitalization efforts is what prompted us to focus on this contextual variance [13]. However, there is a dearth of literature on the topic of how digitalization affects ESG performance in a business-to-business setting.

Although existing studies have verified the potential influence of digitalization on ESG performance [11,13,14], there still exist dual theoretical gaps in its mechanism of action. In view of this, this paper argues that the existing literature has largely ignored the role of digitization in improving ESG performance in the Asian context. In addition, the current literature on digitalization focuses more on its direct impact on ESG performance, while few previous studies have directly demonstrated the mechanism by which digitalization impacts ESG performance. Thus, we contend that research into comparisons across industries is crucial because it teaches businesses how to behave and communicate with their stakeholders in different contexts. On top of that, by comparing different sectors, businesses may see what works and, if feasible, implement those techniques. If practitioners want to participate successfully in digitalization practices according to their operational domain, they need to have a firm grasp of the basic contextual variances that exist. Companies can use this knowledge to direct their investments on digitalization-enhancing organizational capabilities and communication strategies. As an example, service companies may find it challenging to participate in digitalization initiatives that generate value because they invest less in innovative capabilities than product companies [18–20]. Therefore, our study seeks to address the following research questions:

RQ1: "What impact does digitalization have on ESG performance"?

RQ2: "Does environmental uncertainty moderate the relationship between digitalization and ESG performance"?

RQ3: "Do contextual variables (i.e., B2B vs. B2C, products vs. services, and IT intensity) moderate the relationship between digitalization and ESG performance"?

Our study makes significant contributions to the following bodies of knowledge: First, our study explored the influence of digitalization on ESG performance under different contexts. Academics have mostly looked at how digitalization affects environmental and social responsibility performance from a single angle [14,21], but they have not done nearly enough research into the mechanisms that link digitalization to ESG performance. Second, the importance of digitalization to ESG performance is thoroughly examined in this paper. Some researchers argue that digitalization can improve corporate performance and affect ESG performance by making management less short-sighted [10,17,22]. Our research delves deeper into the role of uncertainty environment in the relationship between digitalization and the ESG performance of organizations, from the perspective of business management. Third, industries that rely heavily on information technology (IT) and those that deal with business-to-business transactions (B2B vs. B2C) are likely to see a more intense impact from digitalization on ESG performance. Fourth, the findings enhance confidence for organizations that are now implementing, planning to implement, or are reluctant to embrace digitalization by experimentally illustrating the tangible business

value of digitalization over time. Ultimately, our findings offer significant insights into organizations aiming to enhance returns on digitalization investments across various sector contexts (i.e., complexity, dynamism and magnificence).

The remainder of this research is structured as follows: The second section shows our theoretical foundation and the hypotheses development. The third section indicates the research method and data analytics approach. The third section demonstrates the analysis and hypotheses testing. The fourth section shows our study discussion and implications for theory and practice. The last section shows our study limitations and future research directions.

2. Literature Review

2.1. Digitalization

Digitization has revolutionized communication methods, promoting unprecedented connectivity. Social media platforms, instant messages and videoconference tools have become essential in filling geographic divisions, improving interpersonal interactions and promoting global collaboration [23,24]. This change has allowed individuals to communicate more effectively and frequently. However, dependence on digital communication also raises concerns concerning the erosion of face-to-face interactions and the potential for digital fatigue, which can lead to social isolation [25]. A previous study notes that the proliferation of digital tools has reshaped customer interactions and improved commitment and satisfaction while simultaneously posing challenges related to an overload of information. In the commercial context, digitization has become synonymous with transformation [26,27]. Companies are increasingly adopting digital commercial capacities to improve operational performance and customer satisfaction [28–30]. The integration of technologies such as artificial intelligence (AI), metadata and cloud computing has rationalized business processes, allowing more enlightened decision making and an improvement in customer experiences [31]. The emergence of electronic commerce platforms has enabled small and medium-sized enterprises (SMEs) to reach larger markets, promoting growth and competitiveness [32]. However, the digital fracture remains an important barrier; not all companies can pass on digital platforms, which potentially exacerbates inequalities on the market [33]. For SMEs, the implementation of full customer care frames has proven to be crucial to improve customer satisfaction and stimulate business growth [34,35].

In addition, digitization has revolutionized customer experience through interactive marketing strategies that take advantage of AI and big data [17,22]. This transformation allows companies to adapt their offers to individual preferences, by promoting a personalized shopping experience. However, the constant monitoring of consumer behavior can lead to ethical dilemmas associated with confidentiality and data security [36]. These challenges require a discussion on the appropriate balance between personalized services and consumer rights. The continuous evolution of digital tools, such as ChatGPT and other generative AI technologies, underlines the growing integration of artificial intelligence in various sectors, improving the efficiency and efficiency of commercial operations [37]. The rise of these technologies raises critical questions about future workforce and employment automation. Although AI can improve business processes, it is a threat to certain employment sectors, requiring the adaptation and reskilling strategies of the workforce [38]. The confluence of innovative digitization and marketing strategies also raises essential considerations for consumer behavior. The emergence of the behavior of showrooming, watching and omnichannel shopping illustrates the complexities of modern interactions of consumers [39,40]. While digitization allows consumers of information and choices, it can simultaneously overwhelm them, leading to fatigue and dissatisfaction with their

decision [41]. Thus, companies must navigate these challenges by adopting effective digital strategies that resonate with contemporary consumer expectations.

Digitization has fundamentally reformed the retail industry, which leads to significant alterations in consumer behavior, the efficiency of the supply chain and competitive strategies [42]. As the retail panorama evolves, companies face challenges and opportunities promoted by these changes. The continuous integration of technology in the retail sector not only improves operational capabilities but also transforms the way consumers interact with brands, which requires a more detailed examination of the intricate dynamics of the game [43]. The influence of digitalization on consumer behavior is particularly deep. As highlighted by prior exploration, the advent of information technology has remodeled the consumer decision-making processes [44]. Online purchases have been deeply rooted in the purchase habits of consumers, which is confirmed by prior research, which points out that electronic commerce platforms take advantage of artificial intelligence to offer personalized experiences, significantly impacting consumer preferences and purchase options [45]. In addition, a prior study emphasizes the role of social media marketing to alter the primary decisions made by consumers in the fashionable retail industry, showing that online interactions can build or erode the loyalty of the brand quickly [46,47].

Previous examinations discuss the unique changes caused by the pandemic, which exacerbated the dependence of digital channels while leading companies to reassess their client participation strategies [48]. A prior study provides a look focused on implications for electronic businesses in Saudi Arabia, suggesting that changes towards online purchase habits probably persist, creating a long-term dependence on digital platforms for access to the consumer [49]. Significantly, the appearance of digital technologies facilitates the superior efficiencies of the supply chain. Prior exploration states that the implementation of marketing of the digital age improves the direct interactions of the client, resulting in an optimized management of the supply chain through data analysis and inventory management in real time [50]. A previous investigation explores how technological innovation in marketing can improve response capacity within the supply chain, which makes the processes more agile and, therefore, are better aligned with market demands [51]. In this context, a prior study observes that omnichannel strategies allow a perfect integration of logistics and the flow of information, which leads to greater client satisfaction and loyalty [52]. However, although digitalization offers substantial efficiency opportunities, it also presents several challenges. Companies are often hindered by the rapid rhythm of technological change, which can lead to obsolescence and increased competition [53]. Technology dependence can create a double threat of cybersecurity risks and operational vulnerabilities. Previous examinations highlight that the safety of consumer data remains a critical concern that can dissuade consumers to completely adopt digital platforms [54]. Therefore, companies must achieve a balance between the use of technology for efficiency while guaranteeing the protection of consumer data and trust. The competitive strategies of companies are also evolving in response to digital transformation. One prior study suggests that the introduction of the Metaverse in retail provides innovative means of participation, which can offer a sustainable competitive advantage for companies that accurately navigate this panorama [55]. At the same time, a prior exploration describes how artificial intelligence plays a crucial role in the configuration of marketing strategies, which allows brands to participate in strategies that are proactive instead of reactive, thus creating a different position in the market [56,57].

2.2. Digitalization and ESG Performance

According to modern institutional theory, business digitization draws external attention and creates institutional pressures, compelling firms to enhance their ESG performance

to satisfy the legitimacy requirements of the external environment [21]. Signaling theory posits that the utilization of digital technology as a favorable market signal can diminish information asymmetry, ease financing constraints, safeguard expenditures that fulfil ESG criteria, mitigate agency issues, curb managerial myopia, prioritize long-term green development and bolster companies' commitment to enhancing ESG performance [28]. Stakeholder theory posits that digitization enhances the social and governance aspects of company performance by augmenting transparency and information distribution while fulfilling stakeholder expectations for corporate social responsibility and information accessibility [1].

Digitization is increasingly recognized as a double-edged sword in the field of environmental, social and governance performance (ESG), offering both improvements and challenges for organizations aimed at integrating sustainability and social responsibility in their operations. In recent years, vague research has examined the complex relationship between digitization and ESG performance, with targeted attention to the role of technological progress and data management practices. The arrival of new technologies such as artificial intelligence, the Internet of Things (IoT) and blockchain have transformed the landscape of organizations that strive to improve their ESG performance. For example, prior research illustrates that digital transformation in China considerably improves ESG performance by facilitating transparency, responsibility and sustainability in business practices [40]. The proliferation of digital communication channels allows companies to engage more effectively with stakeholders, promoting a culture of social responsibility [55]. In addition, the integration of digital tools allows companies to monitor their environmental impact in real time, causing more enlightened decision-making processes that potentially reduce the negative effects on the environment [9,26].

An essential element of digitization in ESG performance facilitation is data management. Technological progress has enabled organizations to collect large amounts of data, which can stimulate informed decision making and strategic planning concerning environmental and social governance. A previous study underlines the importance of effective data management practices to achieve good ESG performance, emphasizing that organizations must take advantage of digitization not only to collect data, but also to analyze it and use it critically for significant decision making [32,45]. Thus, the capacity to analyze large sets of data can allow companies to identify the areas of improvement and operational ineffectiveness that can be addressed in the pursuit of sustainability [40]. In addition, the extent to which organizations use digital tools to improve their ESG performance is notably influenced by their commitment to sustainability as a basic commercial strategy. Previous explorations show that organizations that adopt a holistic approach to the integration of the principles of digitization and ESG not only improve their performance but also improve their competitive advantage [37,50]. This indicates that digitization is not only a functional tool but can serve as a strategic catalyst for wider durability objectives. However, companies that consider digital initiatives as isolated projects, disconnected from their ESG objectives, can miss important opportunities to generate a transformer change in their practices and results. The next section demonstrates the conceptual framework and the development of the study hypotheses.

3. Conceptual Framework and Hypotheses Development

We developed an integrated model that explains the relationship between digitalization and ESG performance under different contexts (see Figure 1).

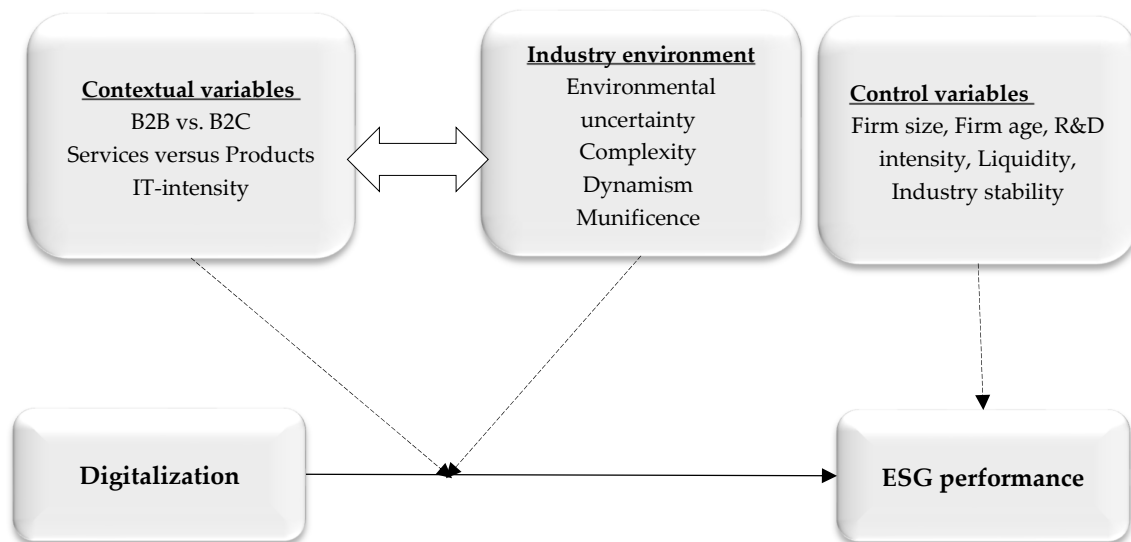


Figure 1. Conceptual framework.

3.1. The Link Between Digitization and ESG Performance

Digital transformation implements systematic innovation in company operations. By employing digital technologies (i.e., “big data, blockchain, artificial intelligence”) to facilitate transformations in production and operations, organizational structure, corporate culture, and business models, firms can significantly enhance their capacity to implement ESG practices [58]. The digital transformation of enterprises enhances resource efficiency by offering technical support for improving ESG performance through R&D innovation or the adoption of advanced digital technologies. This facilitates better resource utilization and the precise management of pollution emissions, thereby promoting pollution reduction, energy conservation and bolstering enterprises’ environmental protection performance [59]. Conversely, digital transformation exerts a regulatory influence, as digital technology significantly enhances data mining, processing and analysis capabilities, bolsters business decision making and improves production and operational efficiency [60], while also augmenting information transparency. Consequently, technology can mitigate the opportunistic conduct of managers; specifically, behaviors that yield adverse social and environmental consequences will be more readily anticipated and identified in enterprises equipped with modern digital infrastructure [61]. Consequently, digital transformation can enhance business ESG performance by improving governance.

Furthermore, as investors place greater importance on ESG performance [62], subpar ESG performance signifies a deficiency in environmental and social responsibility, rendering companies less appealing to investors. The digital transformation of companies enhances information transparency for investors, thereby compelling firms to prioritize environmental and social responsibility performance, as ESG-related information becomes more accessible through this transformation. In recent years, researchers have concentrated on the mechanisms via which digitization can affect environmental (E) performance. Initially, digitization can assist firms in regulating their pollutant output. The utilization of digital technology is an effective method for addressing dynamic environmental issues, including air pollution, carbon emissions, wastewater treatment and climate change [63]. Secondly, digitization can enhance energy efficiency and facilitate sustainable growth. For instance, regarding energy efficiency or renewable energy utilization, businesses might adopt intelligent and sustainable manufacturing through the deployment of digital technologies [64]. Consequently, digitization has the potential to enhance the environmental ratings of organizations.

A high level of firm digitization can enhance environmental quality and elevate the environmental performance of the firms themselves [32,50]. Digital twins, infinite convergence and self-iterative digitization can markedly enhance energy and material efficiency, diminish carbon emissions during manufacturing and further propel the optimization of production and carbon emissions throughout the entire industrial chain [21,30]. Moreover, the deployment of digital technology can enhance process flow via automation advancements in production and elevate the digital energy management capabilities of firms. Current research indicates that corporate digital transformation markedly decreases pollutant emissions, minimizes manufacturing waste and facilitates energy conservation and emission reduction, hence enhancing environmental performance. Secondly, in terms of social implications, comprehensive digitization as a systemic strategic transformation affects various stakeholders to a significant degree [18]. Robust digitization serves as a crucial digital platform to facilitate value generation for empowered stakeholders inside the organization. Data, as an innovative instrument for social governance, can significantly enhance analytical capabilities and decision-making processes within enterprises, offering a novel approach to address intricate social challenges [20,41]. Ultimately, in terms of corporate governance, business digitization facilitates a reduction in information asymmetry and enhances rational analysis and decision making, thus positively impacting the methodology and efficacy of corporate governance [38]. Moreover, digitization can improve ESG performance by liberating organizations from their ingrained mindset, hence increasing their adaptability in developing business strategies and management frameworks, fostering a virtuous cycle of corporate governance. Therefore, we propose the following hypothesis:

H1: *“Digitalization has a significant and positive impact on ESG performance”.*

3.2. “The Moderating Effect of Environmental Uncertainty”

Digitization has emerged as a transforming tool for organizations that navigate the complexities of environmental uncertainty. The unpredictable nature of climate change requires that companies adapt to the conditions that change rapidly, and digital technologies facilitate this adaptation by improving the collection and data analysis capabilities. Through the integration of advanced information systems, companies can capture real-time data on environmental variables, which, in turn, informs decision-making processes aimed at mitigating the risks associated with climate-related interruptions [22,65–67]. The intersection of digitalization and environmental management offers organizations a strategic advantage: By taking advantage of the power of the data, companies can develop adaptive strategies that not only address immediate environmental challenges but also promote long-term resistance.

The advancement of information and communication technologies (ICT) has played an important role in the remodeling of environmental performance and business sustainability initiatives. Innovations such as the Internet of Things (IoT), big data analysis and cloud computing allow a comprehensive monitoring and evaluation of environmental impacts [68]. These technologies allow organizations to access and analyze large amounts of data more efficiently, which is crucial to identify trends, predict future environmental scenarios and evaluate the effectiveness of sustainability practices. By taking advantage of these advances, companies are better equipped to implement specific interventions that align with sustainability objectives, thus reducing their ecological footprints [69,70]. In addition, the influence of digitalization is particularly pronounced in the ecology of supply chains, where it acts as a vital facilitator of sustainable practices. The integration of digital tools allows greater transparency, traceability and efficiency in all supply chains, which facilitates compliance with environmental regulations and standards [71]. For example, the use of blockchain technology in supply chain management can provide unprecedented

levels of visibility, allowing interested parties to track the environmental impact of their products from the supply of raw materials to final consumption [72]. This level of transparency not only improves responsibility but also encourages consumer confidence, which is increasingly linked to ecological commercial practices.

In addition, the application of predictive analysis and automatic learning within the operating contexts allows organizations to proactively manage environmental risks through forecasting possible interruptions and identifying opportunities for sustainable innovations [35,40]. For example, organizations can use predictive models to optimize the allocation of resources and minimize waste, which ultimately promotes greater efficiency within their operations. By integrating digital solutions into their sustainability frameworks, companies can create adaptive strategies that align with dynamic environmental conditions and promote sustainable development. The interaction between digitalization and environmental uncertainty underlines the critical role that technological advances play in the configuration of organizational responses to climate challenges [73]. By improving data collection, improving decision-making processes and promoting sustainable practices, digitalization is a fundamental pillar in the search for resilience in the midst of an environmental panorama in constant evolution. The evidence presented in the literature emphasizes that organizations that effectively integrate digital technologies in their operations are better positioned to navigate uncertainties and positively contribute to broader sustainability efforts. Digitization deeply influences business decision making and the development of sustainable practices in the face of environmental uncertainty [74]. While organizations are sailing in the complexities of an increasingly volatile market landscape, the adoption of digital tools improves flexibility and resilience in decision-making processes. Previous exploration pointed out that digital platforms allow companies to take advantage of real-time data analysis, allowing more reactive and enlightened strategic choices [38,75]. This perspective aligns with prior studies, which affirm that the incorporation of digital technologies facilitates the planning of scenarios and predictive, crucial modeling to anticipate the potential disturbances induced by climate change or market fluctuations [21,40,58,62,76].

In response to environmental instability, companies have adopted various digital innovation strategies, including automatic learning algorithms for predictive maintenance, blockchain for transparency in supply chains and the Internet of Things (IoT) for resource management [33,50,65,77]. These technologies rationalize not only operations but also improve the agility of organizations in adjusting their practices according to real-time environmental data. Companies are able to create more robust operational frameworks that can withstand uncertainties, thus strengthening resilience [18,46,78]. Therefore, we propose the following hypothesis:

H2: *“Environmental uncertainty moderates the digitalization–ESG performance relationship”.*

3.3. Heterogeneity Effect of Digitalization on ESG Performance

This article examines the distinct conditions of several industries and organizations to attain a thorough comprehension of the influence of digitalization on ESG performance. The results demonstrate that the influence of digitalization on ESG performance is heterogeneous, exhibiting varying degrees of impact contingent on factors such as environmental uncertainty, complexity, dynamism, munificence, B2B vs. B2C, services vs. products and IT intensity.

We posit that inherent differences between services and products lead to a greater impact of digitalization on ESG performance among product firms. Compared with services, firms that compete primarily on products/goods possess greater innovation capabilities [30,44,66,79], as they develop well-structured processes and possess resources to create

innovations [80] and are easier to evaluate [60]. These differences explain why competitive product firms exhibit categorically higher customer satisfaction than competitive service firms [45,81], a difference that persists over time and across countries [82,83].

The extant literature indicates that innovative capabilities are a necessary ingredient to increase the effectiveness of digitalization on ESG performance [60,84]. There are two possible explanations for this effect. A previous exploration explained the underlying mechanism using institutional theory. The researchers posit that stakeholders are more likely to perceive CSR as a positive firm activity if the firm also is meeting its main responsibilities well, such as offering high quality, innovative products that address customers' needs [85]. On the other hand, a prior study found that innovation capabilities help firms to engage in value-creating CSR activities by enabling firms to incorporate CSR strategies in their product innovations [86]. Similarly, research found that innovation capabilities can increase the effect of CSR on new product innovations [87,88], which is expected to increase customer satisfaction. Since service firms (versus products) have a long tradition of weaker performance on innovative capabilities [65,81,89], we expect a lower impact of digitalization on ESG performance.

Digitization has profoundly transformed the operational scenario of business companies for business (B2B) and consumer business (B2C), leading to divergent effects on major performance metrics such as customer involvement, operational efficiency and revenue growth. Understanding these differences is crucial for companies that aim to take advantage of digital technologies to improve their competitive advantage [90]. Customer involvement manifests itself differently in B2B and B2C environments due to distinctions inherent to the public and engagement methods. B2C companies tend to use scanning to create direct and personal customer interactions and employ social media, targeted advertising and custom marketing strategies to improve brand loyalty and customer experience [91,92]. On the other hand, B2B companies face a more complex scenario of engagement, as their transactions usually involve multiple stakeholders and longer decision-making processes. Consequently, digitization efforts in B2B companies are often concentrated in the construction of long-term relationships, with tools such as Customer Relationship Management systems (CRM) playing a key role [33,50,66,93]. For B2B companies, the improvement of customer involvement through digital platforms can lead to better relational results that exceed the most immediate transactional benefits observed in B2C settings.

In addition, operational efficiency is another critical metric of performance influenced by digitization, with variations between B2B and B2C companies mostly arising from the nature of their operations [35,80,88]. B2B companies usually deal with complex supply chains, where digitization can optimize processes, improve communication and automate transactions [32,66,70,86]. For example, the implementation of digital process resources can significantly improve competitive performance, facilitating better coordination among supply chain partners, emphasizing that in the B2B context, digitization is critical to achieving operational excellence as companies adopt advanced data analysis and automation technologies to reduce costs and improve service provision [27,55,86,94]. On the other hand, B2C companies usually take advantage of digital tools for customer service management efficiency and engagement, where direct access to customer data allows rapid response capacity and enhanced service experiences [31,66,86].

The availability of complementary human and technological IT assets inside a corporation or its network (e.g., industry or geographic region) is a key mediator of the commercial value of IT and, more specifically, BDA, according to much empirical research [20,66,86,90]. For instance, prior research demonstrated that, in comparison to other industries like agriculture, mining and construction, businesses involved in the production or heavy use of information technology (IT) (e.g., electronic equipment, industrial machinery and

equipment) have experienced substantially larger productivity gains in the last several decades [65,77,86]. Research from high-information-intensive sectors (such as banking, insurance, retail and healthcare) shows that IT investments boost firm performance more than research from low-information-intensive sectors (such as construction and certain manufacturing industries), according to prior study assessment of the literature on IT investment [31,55,77,88,95]. A prior study revealed that the data and IT intensity of an industry significantly influenced the adoption of big data analytics and its ability to increase business efficiency [43]. This study focused on BDA especially. Lastly, in a study on the impact of big data skills investments on firm productivity, the researchers revealed that only data-driven industries could fully benefit from big data investments [30,65,77,87]. They also found that there was a positive interaction effect between a firm's investment in big data skills and the availability of big data skills in their industry.

The dynamism and complexity of modern environments significantly influence organizations' strategies to adopt digitization as companies face multifaceted challenges and take advantage of emerging opportunities in various sectors. As digitization continues to reformulate business landscapes, it is essential to understand its implications in this context. Organizations operate in environments characterized by rapid technological advance and consumer evolution behavior, requiring agility in adapting strategies to adopt digitization. A previous study emphasizes the fundamental role of network digitization and capacity as leading facilitators of business models innovation and sustainability performance [17]. The research points out that environmental dynamism moderates this relationship, suggesting that organizations must continually reassess their strategies to remain competitive in a constantly changing scenario. This statement is reinforced by prior research, which explores the facilitating role of dynamic resources on the driver of changes in the digital business model [38]. In responding to dynamics in their environments, organizations can take advantage of digitization to innovate and realign their business models effectively.

The challenges in adopting digitization are multiple, particularly in relation to the orientation of digital innovation. Previous studies exploit the connection between the adoption of digital technology and the company's performance in the textile industry [43,60]. They illustrate that companies with strong digital innovation guidance experience improved digital transformation results, reinforcing the notion that organizations should cultivate these capabilities to navigate the complexities of the modern market. On the other hand, the absence of such guidelines may prevent organizations' efforts to capitalize on digital opportunities, highlighting the dichotomy inherent in digital transformation strategies. The influence of digitization on organizations extends beyond mere operational adjustments. A prior study examines the dynamics of the adoption of cloud computing services, noting that the complexity of organizational contexts significantly affects the likelihood of successful adoption [26]. This perspective aligns with the results of a previous exploration, which elucidates the organizational effects of digitization [50]. The authors of that study postulate that organizations must develop a deeper understanding of their unique contexts to create effective digital strategies that address specific challenges and maximize benefits. The interaction between strategy and information systems emerges as a crucial theme in the navigation of complexities posted by modern environments. Previous examinations offer a configuring perspective on digital business strategy, arguing that organizations should carefully balance different elements of their strategies to mitigate the risks associated with digitization [42,48,51]. This requires an intricate understanding of how various digital initiatives interconnect in organizational structures, improving a company's ability to maneuver in complex environments. Therefore, we propose the following hypotheses:

H3: *"The impact of digitalization on ESG performance is greater for products than for services".*

H4: *“The impact of digitalization on ESG performance is greater for B2B than for B2C firms”.*

H5: *“The effect of digitalization on ESG performance is higher in IT-intensive industries than it is in other industries”.*

H6: *“In more complex, dynamic, munificent industry environments, digitalization is associated with a greater impact on ESG performance”.*

4. Research Methodology

4.1. Sample and Data Collection Process

Certain Asian nations were selected as the analytical context for the following reasons: Initially, swift economic expansion and an emerging middle class in Asia have propelled an increase in demand for sustainable practices and ethical company conduct [96]. Escalating stakeholder pressure, along with heightened regulatory scrutiny, compelled Asian enterprises to proactively engage with ESG principles. Examining the influence of these pillars on Asian nations, together with the associated problems and possibilities, may yield significant insights into the global business environment. Secondly, the Asia region’s varied cultural and legislative landscape provided a fertile framework for examining the intricacies of ESG performance and implementation [97]. Analyzing various methodologies for sustainability reporting, stakeholder engagement and corporate governance in nations like China and Japan may yield insights into the intricacies of implementing global standards within local frameworks [98]. Third, Asia has been in the forefront of implementing sophisticated technologies, like artificial intelligence and blockchain [99]. This technology advancement has been revolutionizing the profession, indicating enhanced productivity, greater transparency and novel approaches to risk management. Examining the impact of digitization on Asian enterprises may provide significant insights into the potential and challenges posed by new technologies across several business sectors.

This study evaluates the impact of digitization on the economies of Asia by selecting 19 Asian countries with the highest GDP per capita: “Bahrain, China, Hong Kong, Indonesia, Japan, Jordan, Kazakhstan, South Korea, Kuwait, Lebanon, Malaysia, Oman, Qatar, Saudi Arabia, Singapore, Sri Lanka, Thailand, the United Arab Emirates and Vietnam”. Utilizing data from “International Monetary Fund (IMF) reports”. The researchers utilized a dataset of enterprises listed on the “equity exchanges of 19 Asian countries”, covering the period from 2015 to 2024, for their investigation. Consequently, we aimed to validate our assumptions within the 2015–2024 timeframe to enhance the ESG literature. We begin with “Thomson Reuters Asset4 (Asset4)”, which offers ESG scores to formulate our sample for a cross-country analysis from 2015 to 2024. The Thomson Reuters ASSET4 database provides extensive ESG data, including annual economic information on around 5000 firms across over 50 countries. We integrate ASSET4 data with corporate financial information sourced from DataStream via Thomson Reuters Eikon. Subsequently, we exclude organizations with absent data on ESG ratings, moderator variables, financial information and control variables. Ultimately, following the execution of several stringent screening protocols, a final sample of 1839 firms was obtained, resulting in 18,390 firm-year observations and creating a balanced panel data set. Table 1 shows the main characteristics of our study sample.

Table 1. Sample composition.

Industry	Observations/Year									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Chemical industry	289	289	289	289	289	289	289	289	289	289
Industrial tools	217	217	217	217	217	217	217	217	217	217
Business services	159	159	159	159	159	159	159	159	159	159
Machine building	156	156	156	156	156	156	156	156	156	156
Transportation equipment	151	151	151	151	151	151	151	151	151	151
Electronic equipment	134	134	134	134	134	134	134	134	134	134
Investment services	93	93	93	93	93	93	93	93	93	93
Paper industry	90	90	90	90	90	90	90	90	90	90
Quarry industry	87	87	87	87	87	87	87	87	87	87
Communications	79	79	79	79	79	79	79	79	79	79
Utilities industry	72	72	72	72	72	72	72	72	72	72
Business support services	63	63	63	63	63	63	63	63	63	63
Food industry	61	61	61	61	61	61	61	61	61	61
Primary metal industry	57	57	57	57	57	57	57	57	57	57
Air transport services	51	51	51	51	51	51	51	51	51	51
Insurance carries	49	49	49	49	49	49	49	49	49	49
Others	31	31	31	31	31	31	31	31	31	31
Total	18,390									

4.2. Variables Operationalization

4.2.1. ESG Performance

We followed prior studies [100,101] to assess ESG performance by employing a natural logarithmic transformation of the ESG score. The choice to utilize this scale score was driven by the temporal variability of the score resulting from data source factors [102]. This approach of employing the natural logarithm was selected to reduce errors during data alterations [103]. The use of ESG scores provided a clearer evaluation of companies' ESGP status for users and acted as a more reliable measure of companies' sustainable performance [104]. Table 2 shows our study variables operationalization.

Table 2. Variables operationalization.

Construct	Role	Definition	Source (s)
Digitalization	Independent variable	<p>“Digitization refers to firm digital transformation by applying traditional management, operation, and service models to achieve the intelligence, automation, and science of management, operation, and service through digital technology applications”. “Referring to Wu et al. (2021) [105] and Fang et al. (2023) [106], we use the text analysis function of Python 3.10.x to construct independent variable Digit in the following three steps: (1) summarize the specific keywords related to digitization based on the articles in the academic field and documents in the industrial field; (2) conduct the word frequency statistics of the annual reports of each listed firm in each year based on the keywords that have been mentioned, and after processing, obtain the panel data; (3) add 1 and take the natural logarithm to obtain the overall index of firm digitization, considering that this kind of word frequency data has typical “right bias” characteristics”.</p>	Thomson Reuters Eikon Datastream.

Table 2. Cont.

Construct	Role	Definition	Source (s)
ESG performance	Dependent variable	“The ESG performance was determined by applying a natural logarithmic transformation to the ESG score, derived from previous studies by Barbieri and Pellegrini (2022) [100] and Saleh et al. (2023) [101]. The decision to use this scale score was motivated by the variability in the score over time due to data source considerations [102]. This method of using the natural logarithm was chosen to minimize errors during data modifications [103]. The utilization of ESG scores offered the advantage of facilitating a more straightforward assessment of firms’ ESGP status for users [104] and served as a more robust indicator of firms’ sustainable performance [105]”.	Thomson Reuters Eikon Datastream
Environmental uncertainty	Moderator variable	“We measured dynamism as the volatility of sales in a dominant industry over a period of 5 years”	Thomson Reuters Eikon Datastream
IT intensity	Moderator variable	“Binary indicator variable: 1 indicates that the firm is in an IT-intensive industry; otherwise, 0”	Thomson Reuters Eikon Datastream
Dynamism	Moderator variable	“We measured dynamism as the volatility of sales in a dominant industry over a period of 5 years (Xue et al., 2023; Zhu et al., 2021)” [81,107]	Thomson Reuters Eikon Datastream
Complexity	Moderator variable	“We used the Herfindahl index to measure complexity (Xu et al., 2024)” [97]. “Herfindahl index is a well-known measure for market concentration”.	Thomson Reuters Eikon Datastream
Munificence	Moderator variable	“We used the sales growth in a dominant industry over a period of 5 years to measure munificence (Xu et al., 2024)” [97]	Thomson Reuters Eikon Datastream
Firm age	Control variable	“We operationalized firm age as the natural logarithm of difference between the current year and founding year”.	The American Hotel & Lodging Association (AHLA) database
Firm profitability	Control variable	“We calculated firm profitability using a firm’s return on assets”.	The American Hotel & Lodging Association (AHLA) database
“Industry stability”	Control variable	“Operationalized as the two-digit SIC industry’s lagged three-year standard deviation of the median sales growth ($t-2, t-1, t$)”.	(Nath & Mahajan, 2011) [92]

4.2.2. Digitalization

Our study followed prior examinations [105,106], employing a text mining methodology via Python, utilizing the companies’ annual reports as the subject of analysis, capitalizing on the accessibility and dependability of the information disclosed within these reports and quantifying and summarizing the frequency of terms associated with digital investment. This task comprises the subsequent steps:

Initially, the annual reports of selected corporations from 2015 to 2024 are gathered and consolidated via the companies’ websites. Secondly, a glossary of essential terms for corporate digital investment was established based on the findings of prior research [107]. The glossary encompasses the following key terms: “data management, data mining, data network, data platform, data center, digital control, digitalization, digital communication, digital platform big data, cloud computing, cloud services, cloud platform, block chain, Internet of Things, informatization, networking, intelligence, wisdom, digital currency, digital technology, digital economy, digital platform, digital infrastructure, artificial intelligence, natural language processing, intelligent planning, intelligent optimization, intelligent question and answer, machine translation, deep learning, robotics, speech recognition, picture recognition, image recognition, neural network, automatic reasoning, OCR, machine learning, machine vision information technology, Internet, artificial intelligence, e-commerce, virtual community, and intelligent manufacturing.” Third, we employed the Python pro-

programming language to analyze the text of companies' annual reports and compute the logarithm of the word frequency of the aforementioned keywords, after adding one, as a proxy for assessing enterprises' digital investment [107].

4.2.3. Environmental Uncertainty

The authors initially quantified ENU based on the coefficient of variation of sales (CV), measured against total assets as per prior research [108] as follows:

$$CV(Si_t) = \frac{\sqrt{\sum_{t=1}^5 \frac{(Si_t - S_{mean})^2}{5}}}{S_{mean}} \quad (1)$$

In which Si_t denotes the sales of business i for the year t . S_{mean} denotes the five-year moving average of sales for firm i , concluding in year t . In accordance with prior study [108], the industry-adjusted sales coefficient of variation was determined by dividing each firm's coefficient of variation by the average of its industry for that fiscal year. Elevated levels signify an increased ENU.

4.2.4. IT Intensity

Based on the proportion of a company's total replicable capital stock, that is, IT capital stock, we used a method for categorizing IT intensity across industries [109,110]. We followed the methodology of previous study and identified IT-intensive industries as those having a stock share of IT capital that was higher than the median [111].

4.2.5. Dynamism

Dynamism was quantified as the sales volatility within a dominant industry during a five-year period [65]. The fluctuation of industry sales was calculated with a two-step methodology. The natural logarithm of annual revenues for all enterprises within each two-digit SIC industry was regressed against a time index variable over a span of five years. The antilogarithm of the standard error of the regression slope coefficient was employed to assess industry sales volatility throughout the specified period.

4.2.6. Complexity

The Herfindahl index was employed to assess complexity [70]. The Herfindahl index is a recognized metric for assessing market concentration. A high Herfindahl index value signifies a highly concentrated industry dominated by a limited number of enterprises. We utilized the reciprocal of the Herfindahl index as the metric for complexity.

4.2.7. Munificence

We employed sales growth in a pre-eminent industry over a span of five years to assess munificence [70]. Industry sales growth was determined by a two-step process. Initially, we performed a regression analysis on the natural logarithm of annual sales for enterprises within each two-digit SIC industry against the index variable of years, spanning a duration of five years. The antilogarithm of the regression slope coefficient was utilized as the metric for industry sales growth over the specified period.

4.3. Model Specification

To test the proposed hypotheses, we developed the following dynamic panel data (DPD) model. Two equations were used to test the relationship between digitalization and ESG performance through contextual variables.

$$ESGP_{it} = \beta_0 + \beta_1 DGT_{it-1} + \beta_2 AGE_{it-1} + \beta_3 SZE_{it-1} + \beta_4 R\&D_{it-1} + \beta_5 LIQ_{it-1} + \beta_6 STB_{it-1} + \varepsilon_{it-1} \quad (2)$$

$$ESGP_{it} = \beta_0 + \beta_1 DGT_{it-1} + \beta_2 AGE_{it-1} + \beta_3 SZE_{it-1} + \beta_4 R\&D_{it-1} + \beta_5 LIQ_{it-1} + \beta_6 STB_{it-1} + \beta_7 DGT_{it-1} \times B2B \text{ vs. } B2C_{it-1} + \beta_8 DGT_{it-1} \times SER \text{ vs. } PRD_{it-1} + \beta_9 DGT_{it-1} \times ITS_{it-1} + \beta_{10} DGT_{it-1} \times ENV_{it-1} + \beta_{11} DGT_{it-1} \times CMX_{it-1} + \beta_{12} DGT_{it-1} \times DYM_{it-1} + \beta_{13} DGT_{it-1} \times MUN_{it-1} + \epsilon_{it-1} \tag{3}$$

where ESGP represents environmental, social and governance performance; DGT refers to digitalization; AGE refers to firm age, SZE represents firm size; LIQ refers to liquidity; STB refers to industry stability; ENV represents environmental uncertainty and ϵ_{it} refers to the error term.

4.4. Causality, Heterogeneity and Statistical Analysis Technique

Even though rigorous exogeneity limits are used by “OLS estimation,” it is likely that independent factors are related to dependent factors’ lagged values and that unobserved variables affect both sets of components. Prior research proposes a panel estimator called “dynamic generalized method of moments” (GMM) that incorporates instruments [107]. This estimator helps to mitigate the effect of unobservable “heteroskedasticity and endogeneity” on the estimate. The “GMM estimation procedure” is a two-stage process. First, we apply first variance to all components of the estimate models to eliminate bias that may be due to “unobserved heterogeneity.” Following the determination of the initial variance, we utilize GMM to estimate all models, including the dependent, explanatory and control components, using lag values. Consistent with earlier research [112,113], the “GMM estimation” method employs two lag values for the pertinent component. Using this strategy has many valid reasons. A previous exploration found that the system GMM estimator can decrease dynamic panel bias by using lag-dependent elements as independent variables from the fixed effects [114]. As for the second point, “the system GMM estimator is considered one of the most robust technologies for unbalanced panels with endogenous variables” [115]. A prior study states that the third point is that the system GMM estimator handles the endogeneity problem by internally constructing instruments utilizing the lags of the model’s components [116]. Furthermore, by examining the multicollinearity that results from including numerous interactions features in a regression model, we identify the factors that lead to an inflation of the variance. We determined the “nonlinear bivariate causality direction ratio” (NLBCDR) in line with the suggestions made by earlier research [117]. According to the findings, the lowest allowable number is 0.7. It was determined that the NLBCDR ratio is greater than the threshold, coming in at 0.849. The study’s findings contradict the idea of a causal relationship. In order to eliminate multicollinearity, we standardize the main effect components before we create interactions [118]. To eliminate worries about simultaneity, we postpone the dependent variables by one period to ensure that the independent and control factors take precedence in terms of temporal order [118]. Table 3 demonstrates the Pearson correlation matrix for the factors in our baseline model.

Table 3. Correlation table.

Variables	Mean	Std.dev	ESGP	DGT	ENV	IT	DYM	CMX	MUN	AGE	SZE	PFT	STB
ESGP	2.319	1.037	1										
DGT	0.284	0.402	0.418 **	1									
ENV	0.184	0.215	0.210 *	0.067	1								
IT	0.163	0.310	0.043	0.043	0.027	1							
DYM	0.301	0.189	0.037	0.078	0.084	0.212	1						
CMX	0.218	0.095	0.019	0.039	0.092	0.034	0.021	1					
MUN	0.0217	0.027	0.031	0.021	0.046	0.219	0.063	0.081	1				
AGE	0.04	0.053	0.136	0.027	0.104	0.029	0.017	0.027	0.091	1			
SZE	0.063	0.142	0.034	0.129	0.127	0.162	0.032	0.012	0.082	0.124	1		

Table 3. Cont.

Variables	Mean	Std.dev	ESGP	DGT	ENV	IT	DYM	CMX	MUN	AGE	SZE	PFT	STB
PFT	0.015	0.047	0.173 *	0.043	0.028	0.048	0.012	0.022	0.043	0.049	0.402 *	1	
STB	0.328	0.201	0.034	0.036	0.024	0.019	0.037	0.067	0.029	0.043	0.029	0.039	1

Note: ESGP = environmental, social, and governance performance; DGT = digitalization; ENV = environmental uncertainty; IT = IT intensity; PFT = profitability; SIZ = firm size; Age = firm age; STB = industry stability; DYM = dynamism; CMX = complexity; MUN = munificence. * *p* value < 0.05, ** *p* value < 0.0.

4.5. Endogeneity Analysis

A potential endogenous relationship between digitalization (DGT) and ESG performance could be a concern in our regression models. Specifically, the relationship between DGT and ESG performance might be influenced by observable heterogeneity, unobservable heterogeneity, time-invariant omitted variable bias and correlated omitted variables bias. To address these endogeneity issues, we employ several techniques, including (a) Heckman’s [119] two-stage analysis and (b) instrumental variable analysis.

4.5.1. Heckman’s (1979) Two-Stage Analysis

Heckman’s model corrects for sample selection bias, which occurs when our sample is not random—e.g., only firms that choose to digitalize are included in our “treated” group, and they may systematically differ in ways that also affect ESG performance. So, if the decision to digitalize is not random, and we only observe ESG performance for firms that do digitalize, our estimates will be biased.

To address any self-selection bias in companies’ digitalization choices, we utilize the Heckman two-stage method [119]. Initially, we employ a determinant model to assess a company’s decision to adopt digitization, represented as a binary factor that equals 1 if the company implements digitalization and 0 otherwise. The “inverse Mills ratio (IMR)” is calculated from the first-stage model and subsequently utilized in the “second-stage model”, as demonstrated in “Equations (1) and (2)”. In the initial model, we choose profitability, firm size, firm age, industry stability, industry growth, complexity, munificence, environmental uncertainty and dynamism.

Table 4 presents the findings of both the first stage and second-stage regressions. The analysis indicates that our findings persist after accounting for self-selection bias. The findings indicate that the coefficient of DGT was positive and significant ($\beta = 4.108$, $p < 0.01$), implying that DGT is a crucial determinant in a company’s decision to invest at maximum capacity. Additionally, the analysis revealed that company age, industry growth, and profitability exhibit a favorable correlation with the deployment of digitalization. Furthermore, environmental uncertainty was found to have a negative impact on the deployment of digitalization. Furthermore, the “inverse Mills ratio (IMR) coefficients” in Models (1) and (2) are negative and statistically significant at the 1% level, indicating that our findings are robust even after adjusting for any self-selection bias.

Table 4. Heckman’s (1979) two-stage analysis.

Second Stage Dependent Variable = ESG Performance			First Stage Dependent Variable = DGT	
Model 4	Model 3	Model 2	(Model 1)	
0.039 ** (4.293)	0.044 ** (5.016)	0.0218 ** (4.129)	-	DGT
0.031 ** (3.780)	0.021 ** (3.129)	-	-	DGT × DYM
0.027 ** (4.102)	-	-	-	DGT × CMX

Table 4. Cont.

Second Stage Dependent Variable = ESG Performance			First Stage Dependent Variable = DGT	
Model 4	Model 3	Model 2	(Model 1)	
0.012 ** (3.239)	-	-	-	DGT × MUN
0.319 ** (4.109)	-	-	-	DGT × IT
0.018 ** (3.120)	-	-	-	DGT × UNC
0.042 (1.038)	0.026 (1.293)	0.134 ** (3.289)	-	
0.029 (1.128)	0.028 (1.218)	0.051 (1.026)	-	DYM
0.030 (1.223)	0.047 (1.248)	0.062 (1.208)	-	CMX
0.013 (1.472)	0.018 (1.234)	0.078 (1.210)	-	MUN
0.210 ** (5.309)	0.397 ** (7.139)	0.127 ** (3.017)	-	IT
0.018 (1.105)	0.024 (1.315)	0.012 (1.329)	0.172 ** (2.038)	UNC
0.130 ** (2.918)	0.108 ** (2.839)	0.179 ** (3.017)	0.271 ** (5.011)	Firm size
0.237 ** (5.120)	0.212 ** (4.89)	0.205 ** (5.128)	0.208 ** (4.612)	Firm age
0.036 (1.116)	0.028 (1.124)	0.035 (1.107)	0.419 * (12.106)	Profitability
0.039 (1.127)	0.017 (1.138)	0.016 (1.061)	0.174 ** (2.419)	Industry stability
				Industry growth
-0.294(7.193)	-0.271 (7.208)	-0.296 (8.219)	-	IMR
0.399 ** (11.203)	0.361 ** (9.016)	0.319 ** (8.210)	-2.189 ** (-6.219)	Constant
Yes	Yes	Yes	Yes	Year fixed effects
Yes	Yes	Yes	Yes	Industry fixed effects
Yes	Yes	Yes	Yes	Country fixed effects
18,390	18,390	18,390	18,390	Observations
0.085	0.085	0.085	0.081	Pseudo
	14.49 ***			R-squared/R-squared
				Test: INVOP β INVOP 3
				FEMOWN 5 0
13.44 ***				Test: INVOP β INVOP 3
				CONTROL 5 0

Note: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.01$.

4.5.2. “Instrumental Variable Analysis in Estimating Our Regression Model”

Correlated omitted factors continue to pose a possibly more substantial concern. An unobserved variable may affect both the implementation of digitalization and ESG performance, resulting in “biased regression coefficients and standard errors”, perhaps creating a misleading association. To mitigate this issue, we utilize instrumental variable analysis. This method alleviates bias from correlated omitted factors, yielding more precise and reliable results. Our study utilizes the “industry-year level digital transformation average as an instrumental variable, positing that firms’ decisions about digital transformation are influenced by peer effects”. The findings of the endogeneity test with the regression outcomes. The F-value in the initial stage is 62.019, significantly exceeding 10, so confirming the appropriateness of the selected instrumental variable. The regression outcomes for the second step are in line with the findings presented in Table 5, as indicated by the initial step. This indicates that our conclusions are robust and reliable.

Table 5. Estimation results for DGT, industry environment and ESG.

					Main Effect	Moderating Effect
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.290 * (4.30)	0.349 ** (5.20)	0.318 ** (5.19)	0.239 ** (4.39)	0.218 ** (4.20)	0.319 ** (6.30)
Lagged ESGP	0.527 ** (12.20)	0.326 ** (5.12)	0.301 ** (5.06)	0.410 ** (8.12)	0.328 ** (6.16)	0.282 ** (4.12)
DGT	0.031 ** (2.08)	0.023 ** (2.36)	0.014 ** (2.29)	0.045 ** (2.38)	0.051 ** (2.19)	0.024 ** (1.62)
Firm size	0.061 (1.28)	0.048 (1.28)	0.051 (1.10)	0.032 (1.29)	0.038 (1.25)	0.035 (1.28)
Firm age	0.028 (1.026)	0.134*(2.91)	0.201 * (4.12)	0.231*(3.78)	0.231*(4.01)	0.177 *(2.78)
Profitability	0.129 * (3.12)	0.040 (1.26)	0.030 (1.06)	0.035 (1.02)	0.048 (1.26)	0.030 (1.29)
Industry stability	0.082 (1.28)	0.102 * (2.41)	0.147 * (3.01)	0.208 * (3.88)	0.204 * (4.06)	0.214 * (4.78)
Industry growth	0.106 * (2.10)	0.118 * (2.89)	0.104 * (2.66)	0.104 * (2.51)	0.132 * (2.77)	0.206 * (4.12)
Moderating effect						
Product		−0.063(1.52)				
DGT × product		0.317 ** (5.07)	0.043 (1.20)			
B2B			0.209 ** (4.12)			
DGT × B2B				0.047 (1.29)		
IT intensity				0.431 * (7.10)		
DGT × IT					0.107 * (2.18)	
					0.319 ** (6.12)	
UNC						−0.132 * (2.89)
DGT × UNC						−0.236 ** (4.20)
DYM						0.218 * (4.12)
DGT × DYM						0.403 ** (7.82)
CMX						0.429 * (8.12)
DGT × CMX						0.633 ** (14.20)
MUN						0.146 * (3.20)
DGT × MUN						0.219 ** (4.01)
Model information						
Number of observations	18,390	18,390	18,390	18,390	18,390	18,390

Note: * $p < 0.05$. ** $p < 0.01$.

5. Results

5.1. The Link Between DGT and ESG Performance

We performed two tests to ascertain the appropriateness of employing the “System GMM estimator” in our study. The initial test is the “Sargan test”, employed to assess the orthogonality of instrumental factors relative to the error term [119]. The “Sargan statistic” is not significant ($p > 0.05$), indicating the null hypothesis that the individual instrumental factors are uncorrelated with the error term cannot be rejected. Consequently, the instruments employed in this study may be regarded as exogenous and suitable. The second test assesses the “autocorrelation in the idiosyncratic disturbances”, excluding the fixed effects. Given that this test is conducted on the residuals of variances, “the first-order autocorrelation (AR1)” is inherently expected to be significant. Consequently, we have to depend on the “second-order autocorrelation in differences (AR2)” to ascertain

the first-order autocorrelation in levels [119]. The statistically insignificant AR2 ($p > 0.05$) indicates that we do not reject the null hypothesis of no serial connection in the idiosyncratic disturbances. Consequently, there is no indication that our “System GMM models are misspecified”.

The first hypothesis assesses the relationship between the independent valuable (i.e., digitalization) and the dependent valuable (i.e., ESG performance). The “dynamic panel GMM estimator with instruments” was used to assess the “regression model”. The “Hansen J test” was conducted to assess the validity of our estimators [119]. Table 5 reports the main results for the relationship between DGT and ESG performance. Model (1) reports the coefficients of DGT, lag ESG and control variables. Model (2) reports the coefficients of DGT, lag ESG, control variables and the moderating role of product vs. service. Model (3) reports the coefficients of DGT, lag ESG, control variables and the moderating role of B2B vs. B2C. Model (4) reports the coefficients of DGT, lag ESG, control variables and the moderating role of B2B vs. B2C. Model (5) reports the coefficients of DGT, lag ESG, control variables and the moderating role of environmental uncertainty. Model (6) reports the coefficients of DGT, lag ESG, control variables and the moderating role of industry environment (i.e., complexity, dynamism and munificence).

All “J-statistics ($p > 0.05$)” in Table 5 demonstrate that the “null hypothesis about the validity of our estimators cannot be rejected”. The DGT coefficients have a positive and significant impact on ESG performance ($p < 0.05$); therefore, H1 was supported. To address the potential endogeneity, two-stage least squares (2SLS) were employed. To validate the justification of 2SLS, the Durbin–Wu–Hausman test was conducted to assess the probable endogeneity of the independent factor. The “Durbin–Wu–Hausman statistic” indicated that residual digitalization was statistically significant. This suggested that the regression findings could be biased when digitalization served as the independent factor. Consequently, the present research conducted a two-stage least squares analysis. The lagged digitalization factor and control variables served as instrumental factors. The “Hansen J test” was performed to validate the instrumental factors. The “Hansen J statistics” validated these instruments as the p -values were insignificant. The outcomes of the 2SLS analysis are presented in Table 6. Consequently, digitalization continued to exert a beneficial influence on ESG performance. Hypothesis 1 was corroborated by OLS, fixed effect and 2SLS regressions.

Table 6. Results of OLS, Fixed effect and 2SLS regressions.

		Dependent Variable ESG Performance					
Variables	VIF	(I) OLS		(II) Fixed Effect		(III) 2SLS	
		Coefficient	t Statistics	Coefficient	t Statistics	Coefficient	t Statistics
(Constant)	1.026	129.037	11.210 **	115.21	7.315	127.0578	9.026 **
DGT	1.19	0.34	5.102 **	0.519	0.599 **	0.618	0.831 **
Firm size	1.364	0.219	4.016 **	0.182	0.210 **	0.254	0.305 *
	1.005	0.062	2.002	0.205	0.251 **	0.41	0.618 **
Firm age	1.218	0.318	6.195 **	0.216	0.248 **	0.11	0.102
	1.204	0.057	2.027	0.084	0.129	0.195	0.219 *
Profitability	1.417	0.299	4.027 **	0.105	0.289 *	0.219	4.072 **
Industry stability			29.36 **		229.18 **		29.42 **
Industry growth							
F-ratio							

Note: ** significant at the 0.01 level, * significant at the 0.05 level.

5.2. The Moderating Role of Environmental Uncertainty

Table 5 shows the results of regression analysis on the moderating role of environmental uncertainty. In line with prior exploration [119], our paper utilized the “dynamic GMM panel estimation” to assess the “regression model” (2). The “Hansen J test” indicates that the null hypothesis, which suggests that the moment requirements were accurately given, cannot be rejected at any significant degree. In addition, there is no significant multicollinearity since all VIF values are less than 10 [119]. The results of our study support H2 that there is a positive interaction impact between DGT and environmental uncertainty on ESG performance ($\beta_1 = 0.391$, p -value < 0.01).

5.3. The Moderating Role of Contextual Variables

Table 5 shows the results of regression analysis on the moderating role of contextual variables (i.e., B2B vs. B2C, products vs. Services, and IT intensity). H3 was supported, as the interaction effect of DGT and B2B versus B2C is significantly negative ($\beta_1 = -0.391$, p -value < 0.01), confirming that DGT is less valuable for B2B firms. It also revealed that the interaction effect of DGT and products versus services is significantly positive ($\beta_1 = 0.407$, p -value < 0.01), confirming that DGT is more valuable for products firms. Therefore, H4 was supported. Finally, the analysis indicated that the interaction effect of DGT and IT intensity is significantly positive ($\beta_1 = 0.619$, p -value < 0.01), confirming that DGT is more valuable for firms in IT-intensive industries. Thus, H5 was supported.

5.4. The Moderating Role of Industry Environment

The positive and significant coefficient of \times complexity interaction ($\beta = 0.633$, $p < 0.05$ in Model 6) shows that digitalization has a greater impact on ESG performance in more complex environments than in less complex environments. The positive and significant coefficient of \times dynamism interaction ($\beta = 0.403$, $p < 0.01$ in Model 6) demonstrates that digitalization has a greater impact on ESG performance in more dynamic environments than in less dynamic environments. Moreover, the positive and significant coefficient of \times munificence interaction ($\beta = 0.219$, $p < 0.01$ in Model 6) demonstrates that digitalization has a greater impact on ESG performance in more munificent environments than in less munificent environments. Thus, H6 is supported.

5.5. Robustness Checks

Several supplementary analyses were conducted for the aim of robust assessments. We start by assessing the possible non-linear impacts of DGT using a quadratic aspect in an “ordinary least squares (OLS) regression” analysis. No indication of a curvilinear link is shown by the statistically negligible squared component coefficient. Second, our conceptual framework included certain demographic characteristics at the individual level, including firm age, company size and location. Our results did not alter, and our analysis reveals that none of these factors significantly impact on the relationship between DGT and ESG performance. We also changed our model such that “time lags” of six months and a year were used instead of the DGT time lag. This is because longer time delays are not considered because the quantity of data decreases significantly with each period. No significant findings for DGT were found in the analysis. Using a non-lagged DGT component, we investigated the link between DGT and ESG performance, but we came up empty. So, our study confirmed that DGT is a predictor of ESG performance. Moreover, the method of two stages of minimum square (2SLS) emerged as a central technique in economic, especially in situations where endogeneity complicates causal inference. The traditional regression of common squares (OLS) presupposes that all explanatory variables are exogenous, which means that they are not correlated with the error term. When

this assumption is violated, OLS estimates can be biased and inconsistent, impairing the validity of the findings [106]. Understanding how 2SLS address these challenges is crucial to contemporary economic analysis. 2SLS aims to solve endogeneity problems using instrumental variables (IVs). This method continues in two stages. First, it foresees the endogenous explanatory variables using the selected instruments, which must be correlated with the endogenous variable, but not correlated with the term of error. The second step involves the regression of the original dependent variable of the values provided from the first stage. This double approach helps to mitigate the bias present in the OLS estimates, replacing problematic regressors with their most reliable instruments [106]. We run two-stage least squares (2SLS) regression and the results indicated that digitization significantly enhances companies' ESG scores after considering possible endogeneity issues (Table 6). Additionally, a different analytical method, robust regression, was conducted. Robust regression was performed to mitigate any biases caused by outliers. The results are presented in Table 7. The results were analogous to those of the OLS, fixed-effect, and 2SLS regressions presented in Table 5 regarding statistical significance and coefficient signs. Furthermore, to evaluate the robustness of the baseline findings, we further utilize an alternate metric of ESG performance. We develop a distinct metric for assessing ESG performance. Consistent with a previous study [120], we initially categorize the ESG_score and partition the sample into 100 groups according to those scores. We next create a discrete variable (ESG_Rank) as the new dependent factor, which ranges from 1 to 100; a higher ESG_Rank indicates superior ESG performance. Our analysis revealed that the coefficients of lagged digitalization are positive and statistically significant, consistent with our baseline results.

Table 7. Further analysis.

Variables	Dependent Variable ESG Performance	
	Coefficient	Robust Regression t Statistics
(Constant)	105.418	6.2430 *
DGT	0.401	4.143 **
Firm size	0.289	3.120 *
	0.081	1.032
Firm age	0.299	3.103 *
	0.078	1.427
Profitability	0.31	4.011 **
Industry stability		27.59 **
Industry growth		
F-ratio		

Note: * $p < 0.05$. ** $p < 0.01$.

6. Discussion and Conclusions

6.1. Key Findings

With this study, we explore the influence of digitalization on ESG performance, in product versus service, B2B versus B2C and IT-intensive contexts. Comprehending the influence of DGT on ESG performance and its mechanisms can aid practitioners and policymakers to develop effective and successful strategies to enhance ESG performance. This study revealed that DGT has a positive effect on ESG performance in different contexts. This positive link is stronger, though still positive, for product, B2B and IT-intensive companies. Moreover, environmental uncertainty moderates the DGT-ESG performance relationship.

Our examination indicated that digitalization is a key predictor of ESG performance in different business contexts. This result is in line with prior research that pointed out that digital transformation has a significant and positive impact on ESG performance [11,20,31,32,46,86,91]. Digitization has emerged as a fundamental driver that transforms ESG into several sectors. The intersection of digital technology and ESG principles establishes the basis for sustainable commercial practices, promoting responsibility and improving transparency. This literature review critically evaluates how digitalization reforms ESG metric by highlighting their benefits, examining persistent challenges and discussing implications for sustainable practices in the corporate landscape. The advent of technologies such as big data analysis, artificial intelligence and blockchain has significantly improved the capacity of companies to monitor, inform and improve their ESG performance [25,66,80,90]. These digital tools provide critical information on the environmental impacts of operations, social commitments with interested parties and governance structures.

By taking advantage of these technologies, organizations can unlock sustainable value, allowing them to make decisions based on data that are aligned with the objectives of ESG [55,72,80]. In addition, digitalization facilitates real-time reports, which improves transparency and responsibility. This timely dissemination of information encourages the improved confidence of interested parties and supports the reputation of an organization, ultimately contributing to the improved financial performance linked to solid ESG metrics. In addition, the role of dynamic capacities has been postulated as a critical mediation factor in the relationship between digital transformation and ESG performance. As established in a prior study [22,46], the ability to adapt and take advantage of digital technologies effectively allows companies not only to optimize their operations, but also to advance their ESG strategies.

A previous examination illustrates that in the context of B2B Korean companies, the effective management of digital technologies can promote sustainable performance by promoting collaboration practices that prioritize environmental concerns [36,55,78]. On the other hand, B2C companies face the challenge of serving a broader consumer base with variable priorities and motivations towards sustainability. This difference is crucial since the client-centered approach required in B2C companies often leads to the pressures of consumers who demand transparency and responsibility in ESG practices. In addition, a previous study argues that the integration of digital technologies can mediate the servitization process in manufacturing companies, which is mainly a B2B phenomenon, thus improving the performance of ESG [32,66]. The results emphasize that digitalization allows B2B companies to take advantage of data analysis and monitoring capabilities to boost ecological innovations. On the contrary, for B2C companies, the rapid evolution of digital and commitment marketing tools presents a challenge and an opportunity. In addition, the results of this study are consistent with the findings of prior study that revealed that the impact of big data analytics on firm performance is greater for firms in IT-intensive industries [43,48].

6.2. Theoretical Implications

This study extends knowledge about the impact of digitalization on ESG performance under different contexts and makes significant contributions to the related literature in three ways. First, our research proves that DGT can boost ESG performance in many types of businesses. When it comes to improving ESG performance, DGT is important in every business environment. According to earlier studies [28,33,75,86], digitalization can only bring about favorable results if it is acknowledged and appreciated.

Second, we find that the effect of DGT on ESG performance is stronger for products versus services, B2B versus B2C and IT-intensive firms. This suggests that a previous finding showing that DGT exerts a greater impact on firm performance for service firms may be short-lived [36,65]. Taking a longer-term perspective, our results show that the impact of DGT on ESG performance is lower for service firms, because it is harder for investors to perceive firms' digitalization activities in service contexts. Our results also extend previous research on digitalization to both B2C and B2B firms. B2B relationships involve larger, more complex and relational transactions that require greater organizational alignment and adaptation [36,55,86,90]. Our results support the notion that greater, more explicit expectations and requirements exist for the alignment of digitalization activities and policies in B2B relationships [27,77,92].

Finally, we stress that environmental uncertainty moderates the association between DGT and ESG performance, which is a significant finding. The impact of ENV as a moderator on the DGT–ESG performance linkages adds complexity to the literature on both contemporary technology (“i.e., blockchain and AI”) and ESG performance, while also providing important insights into the ever-changing relationship between organizational context and strategic decisions. Recognizing the complexity of organizational adaptation, this study goes beyond a static analysis. It is clear that DGT has a favorable impact on ESG performance, but how well the firm handles external environmental issues determines how effective these impacts are [8,13,86]. Adaptive and responsive risk management strategies are essential, but they are typically disregarded in favor of more simplistic models of RBV applications in studies on ESG issues and in the adoption of new technologies. Putting RBV theory in the context of the ever-changing landscape of organizational sustainability initiatives is crucial, as the data show. A crucial area of continuing research in all sectors of economics is the need for firms to cultivate a capacity for change and adaptability if their sustainability initiatives are to remain effective in the face of changing environmental conditions.

6.3. Managerial Implications

This study offers meaningful implications for practitioners, regulators and managers. By adopting digital transformation, managers can reap two benefits. In addition to improving a firm's ESG performance, DGT has monetary advantages including higher productivity and lower costs. The first step for practitioners is to make smart investments in digital technologies that improve ESG performance. These technologies include blockchain, artificial intelligence and the Internet of Things. For instance, the Internet of Things (IoT) can aid in the real-time monitoring of environmental compliance, and artificial intelligence (AI) can be used to optimize manufacturing resource utilization. In addition, practitioners can enhance their ESG goals by using digital technologies to make organizations more transparent and efficient.

When it comes to digitalization, regulators play a vital role, particularly for non-state-owned businesses that lack the capital to invest in technology. Policymakers in charge of overseeing digital platforms can devise measures to incentivize digitalization among these organizations, such as offering digital platform providers preferential pricing or providing additional financial assistance. By learning how digitalization can improve ESG performance, authorities can push for further digitization in the tech and manufacturing sectors. Making a “digital credit system” that rewards businesses for their exceptional digitalization efforts could be a good step in the right direction. Last but not least, authorities can strengthen the system of checks and balances by enacting stringent rules that encourage a larger number of independent directors and encourage thorough oversight by financial experts.

In this context, non-governmental organizations are also quite important. The widespread adoption of digitalization in many industries can be actively promoted and aided by them. Non-governmental organizations can advocate for policies that embrace digitalization as a critical indicator of companies' dedication to environmental, social and governance values. In order to get enterprises to prioritize digitalization, they may also spread the word about how good it is for society and the environment.

Entrepreneurial startups have a one-of-a-kind chance to incorporate ESG concepts into their business models from the very beginning with digitalization. By leveraging digitalization, these new businesses can develop ground-breaking goods and services that address societal and ecological concerns. Some examples of possible solutions are AI-powered trash management systems and IoT-based energy saving apps. Incorporating such efforts into their business strategy helps them achieve better ESG performance while also giving them a competitive edge and helping the environment. Moreover, government organizations can also organize relevant summits and forums to encourage and guide companies in the direction of green innovation using state-of-the-art digital technologies like cloud computing and artificial intelligence. Additionally, these gatherings can highlight sustainable, high-quality development methods, which will encourage businesses to go green in the long run.

6.4. Implications for Policymakers

The ramifications for policymakers are considerably more explicit. Our findings indicate that companies must prioritize digitalization as a crucial factor in enhancing ESG performance. Consequently, in the interest of national welfare, governments ought to offer incentives and intensify pressure on companies to perpetually invest in digitalization. This is particularly applicable to nations with a robust service industry, as ESG performance is more significantly affected by digitalization within this domain. Services frequently have low customer satisfaction ratings due to the above discussed features. As services gain prominence, governments should focus more on digitalization within this sector. Policymakers in advanced economies facing sluggish development may utilize the delayed digitalization of services to stimulate economic growth. Furthermore, our findings regarding the industry environment indicate to policymakers that increased business dynamism, complexity and munificence would further augment the impact of digitalization on long-term economic growth.

Furthermore, policymakers might leverage the findings of this study to formulate rules that promote digital transformation, especially within the service sector, B2B business and more dynamic and complex industrial environments, which demonstrate a more pronounced enhancement in ESGP. Regulatory frameworks are advantageous. This facilitates digital transformation, such as subsidies for green technology adoption or tax incentives for innovation. This would further augment the efficacy of digitalization in enhancing ESG outcomes. Policymakers should also contemplate the influence of digital transformation on corporate sustainability initiatives. This can be achieved by guaranteeing that the infrastructure and technological resources essential for enterprises to develop sustainably are available. Generally, ESG enhances business value while safeguarding stakeholders' interests and mitigating social externalities, such as corruption and environmental damage. Nonetheless, encouraging companies to increase their involvement in ESG remains challenging in emerging markets such as Asian countries. Emerging market firms typically exhibit insufficient profitability and worldwide competitiveness, resulting in a lack of motive or capacity to supply public goods. As digitization enhances both the economic efficiency of firms and their ESG performance, government encouragement of enterprise digitization constitutes a mutually advantageous policy. Furthermore, emerging economies

benefit from being late adopters of digital technologies, allowing the experiences of Asian corporations to be applied to developing nations.

7. Limitations and Directions for Future Research

Our study has some limitations that could be utilized to direct future studies for further examinations. The first limitation is that the research may only be applicable to firms based in Asian nations. Examinations in the future can improve upon this by including more firms from different areas and sectors in the sample. Global differences in corporate governance are one example of a country-specific institutional concern that may mitigate the connection between digitalization and ESG performance and its underlying mechanisms. Research examining our results in different settings is encouraged in future explorations. Second, looking at it from a sustainable development lens, our research finds out how digitalization affects the ESG performance of businesses. Given that digitalization is not a one-size-fits-all solution, we propose that further studies examine the nature of digitalization and how it affects ESG performance across various stages of business life cycles. Our paper also explores the direct effect of digitalization on ESG performance. Further explorations could examine the indirect effects through other variables (i.e., green innovation and internal control). Furthermore, the sample of this study is confined to publicly traded corporations, which typically surpass privately held enterprises in size and profitability. Consequently, our results cannot be immediately extrapolated to unlisted small and medium-sized firms (SMEs).

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