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Exploring the Association Between Artificial Intelligence Management and Green Innovation: Expanding the Research Field for Sustainable Outcomes

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Abstract: Green innovation is essential for achieving sustainable development goals (SDGs), particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 12 (Responsible Consumption and Production), as it fosters environmental and social benefits while also creating new economic opportunities. Despite previous studies actively conducting empirical analyses on green innovation, research on guiding the green innovation process through artificial intelligence remains scarce. This study aims to explore key variables that affect green innovation, thereby promoting the sustainable development of organizations, and to investigate the incentive mechanisms behind it. By uncovering the internal and external factors that drive green innovation and their interactions, we can better understand and optimize the process of fostering green innovation. Unlike previous studies, this research not only explores variables and verifies main effects but also provides and validates a research model related to the occurrence of green innovation. Additionally, this study determines the extent to which artificial intelligence management influences green innovation through knowledge sharing and examines whether an innovative culture moderates the impact of artificial intelligence management and knowledge sharing on green innovation, as well as whether it moderates the mediating effect of knowledge sharing within the model. Therefore, this study collected data from 331 adult employees of SMEs across 23 provinces, cities, and districts in China and conducted empirical analyses, including confirmatory factor analysis (CFA) and reliability analysis. The results indicate that artificial intelligence management directly affects green innovation and indirectly affects it through the partial mediating role of knowledge sharing. Furthermore, an innovative culture significantly moderates the mediating role of knowledge sharing between artificial intelligence management and green innovation. In exploring the variables of green innovation, this study established an adjusted mediating model and verified its significance. In summary, the causal relationship between artificial intelligence management and green innovation, as demonstrated through this process, contributes to the expansion of the research field and the advancement of SDGs, specifically Goals 9 and 12. The study's findings highlight the importance of integrating artificial intelligence management to enhance green innovation, which is vital for the sustainable development and economic growth outlined in the SDGs.

Keywords: management systems; business innovation; green innovation; innovative culture; artificial intelligence management; moderated mediation model

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1. Introduction

In the realm of sustainable development, green innovation emerges as a cornerstone for progress, encapsulating the essence of environmental stewardship merged with economic vitality [1]. This fusion is not merely an academic pursuit but a practical imperative that resonates with the United Nations' sustainable development goals (SDGs), which aim

to address the most pressing challenges faced by our global community [2]. Green innovation's transformative potential is evident in its ability to catalyze economic growth while preserving the environment, a concept increasingly supported by empirical evidence [3]. Asadi et al. (2020) notes in their systematic literature review, the discourse on green innovation has broadened to include a wide array of industries, each contributing to the collective effort of sustainable practice implementation [4]. Furthermore, the advent of artificial intelligence in this domain has opened new avenues for research, with studies such as those by Alzoubi and Mishra (2024) exploring the potential of AI to enhance green innovation initiatives [5]. These studies collectively advocate for a future where innovation is not only a byproduct of human ingenuity but a deliberate strategy for achieving sustainability in the future.

Innovation has been an essential element in strengthening organizational competitiveness and corporate success, especially in complex business environments. In particular, the importance of innovation in green technology is being emphasized as the development of new technologies that can contribute to a more sustainable future for organizations [6–8]. It explains that green innovation, crucial for organizational success, fortifies the competitive strength and perpetuates sustainable operations. In recent years, there has been widespread attention on green innovation in emerging economies as it enables businesses to achieve sustainable development [9]. Aligned with the environmental policies of China, a substantial number of SMEs have adopted green innovation as a pivotal strategy for sustainable development, thereby enhancing their competitive edge and ensuring long-term viability [10]. Green innovation aims to improve existing products and processes by reducing the consumption of water, electricity, and other raw materials, thereby achieving ecological sustainability [11]. Green innovation can reduce harmful production, bring about efficiency improvements, make products easier to recycle, and enable the reuse of resources [12]. Therefore, the above points highlight the importance of green innovation within organizations.

According to such a research background, this study suggests that the key factor to inspire employees' green innovation is the application of artificial intelligence management. Artificial intelligence management is deemed indispensable for achieving significant cost reductions, safeguarding operational integrity, mitigating adverse environmental effects, and simultaneously enhancing employee cognizance and proficiency in the realm of sustainable innovation [13]. For employees involved in innovation, the use of artificial intelligence management can provide valuable insights into market trends, competitor activities, and emerging technologies [14]. Artificial intelligence management is increasingly recognized as a catalyst for a transformative shift in the innovation paradigm of businesses, propelling the pursuit of independent innovation, synergizing collaborative efforts, and galvanizing employee engagement in sustainable innovation initiatives [15]. As a crucial driving force for innovation, artificial intelligence management can effectively overcome the challenges that companies encounter in pursuing green innovation [16]. Therefore, based on the above theories, in a work environment involving artificial intelligence management, it is likely to inspire employees' intrinsic green innovation. Therefore, this study suggests that artificial intelligence management has the potential to enhance employees' green innovation capabilities.

Artificial intelligence management operates as a system that manifests intelligent behaviors by scrutinizing environmental parameters and executing targeted actions, possessing a significant level of autonomy to achieve predefined objectives [17]. Artificial intelligence management can achieve maximum benefits in terms of resource utilization and regulatory environment, thereby enhancing employees' green innovation [18]. Green innovation is a positively variable that can promote organizational sustainability and development, leading to industry competitive advantage. In addition, green innovation, propelled by sophisticated AI management systems, significantly elevates the environmental performance of SMEs and effectively combats pollution by seamlessly integrating cutting-edge technology and progressive knowledge practices [19]. Therefore, based on

the above perspectives, this study believes that exploring the application level of artificial intelligence management in SMEs and uncovering the causal relationship between artificial intelligence management and employees' green innovation has significant research significance.

This study also aims to examine whether artificial intelligence management can enhance green innovation and identify which factors mediate the process of how artificial intelligence management influences employees' green innovation. Specifically, this study argues that employees' knowledge sharing has a mediating effect between artificial intelligence management and employees' green innovation. Knowledge sharing refers to the exchange of information among organizations, families, or communities [20]. Through the application of artificial intelligence management, organizations can reward employees who demonstrate proactive learning and knowledge contribution more accurately and fairly [21]. Furthermore, based on the investigation of previous studies, it can be found that knowledge sharing has a positive (+) impact on green innovation [22]. Therefore, by integrating artificial intelligence management practices aimed at enhancing energy efficiency and reducing emissions, organizations can equip their workforce with the necessary knowledge and skills, thereby promoting knowledge sharing and stimulating green innovation. Therefore, artificial intelligence management can have a positive impact on green innovation through knowledge sharing.

Furthermore, this study also suggests that the variation in employees' green innovation is mediated by the moderating effect of innovative culture. A culture of innovation is essential for fostering an environment that stimulates innovation, strengthens trust and communication, and encourages the sharing of technological advancements and strategic innovations among staff [23]. Promoting the development of an innovative culture within the organization can create a sustainable environment and provide incentives or cultivate the right mindset among employees to encourage knowledge sharing [24]. Therefore, this study posits that an innovative culture stimulates employees' knowledge sharing, thereby providing the foundation for employees' green innovation. Therefore, it is necessary to explore the moderating effect of innovative culture, as the interaction between artificial intelligence management/knowledge sharing and innovative culture will stimulate the generation of employees' green innovation.

Indeed, the Chinese government initiated the New Energy Demonstration Cities project in January 2014 across 81 municipalities to foster green growth [25]. Internationally, environmental pollution is a critical issue, stemming from accelerated global warming that exceeds the Earth's greenhouse gas absorption capacity [26]. To address this issue, at COP26, the Glasgow Climate Pact was adopted to mitigate CO2 emissions and promote sustainable development. China, in particular, has explicitly stated its "dual carbon" strategy, aiming to achieve carbon peaking by 2030 and carbon neutrality by 2060 [27]. In order to address this, the Chinese government has implemented a series of environmental regulations (ER) and laws to explore and resolve environmental pollution issues [28].

Based on the above research background and theories, it is worth to inspire employees' green innovation has become an urgent issue that today's Chinese SMEs need to address. Overall, the purposes of this study can be summarized as follows: Firstly, through the review of previous research, it has been found that there is relatively insufficient empirical research in the Chinese academic community on artificial intelligence management and employees' green innovation. Therefore, this study elucidates the relationship between artificial intelligence management and employees' green innovation, as well as how artificial intelligence management can stimulate employees' green innovation, and this will contribute to expanding the research field of artificial intelligence management and green innovation.

Secondly, most of the studies have explored the antecedents of green innovation [29,30], validating their mediating and moderating effects in stimulating green innovation [31,32]. However, this study broadens the research scope of green innovation. Furthermore, this study proposes and validates a moderated mediation research model.

Thirdly, artificial intelligence management is a novel concept. This study explicitly identifies the role of artificial intelligence management and explains its significance in organizations. Furthermore, this study elucidates the impact of artificial intelligence management on employees' knowledge sharing.

Fourthly, the majority of research positions innovation culture as either a dependent or mediating factor; however, this investigation assigns it a moderating role and scrutinizes its influence in that capacity. Particularly, by examining the interaction between artificial intelligence management and innovation culture, this study moderates the mediating effects of employee knowledge sharing, thereby stimulating employees' green innovation.

In conclusion, this study synthesizes the current scholarly achievements in the realm of artificial intelligence and its intersection with green innovation research [5,33–39]. The literature encompasses a spectrum of impacts that artificial intelligence management exerts on green innovation, spanning from the deployment of artificial intelligence technology to the moderating influences of dynamic capabilities and organizational capital, as well as cross-national comparative analyses, comprehensive reviews on green artificial intelligence, deliberations on sustainable artificial intelligence concepts, and an exploration of the prospects and challenges associated with green artificial intelligence initiatives. This study argues that there is currently a lack of research on artificial intelligence management in Chinese SMEs and this study elucidates and investigates the role of artificial intelligence management in Chinese SMEs. This endeavor will contribute to the expansion of the research field of artificial intelligence management. Specifically, this study presents a novel research model to examine artificial intelligence management and reveals the process by which it stimulates employees' green innovation. Moreover, this study is regarded as a contribution to expanding the research field of artificial intelligence management and green innovation. Furthermore, this study reveals the level of innovation culture in Chinese SMEs and, through its interaction with artificial intelligence management and employee knowledge sharing, helps understand the role of green innovation in SMEs (see Table 1).

Table 1. Literature Review.

Research Title	Author	Publication Year	Main Findings
Sustainable AI: AI for sustainability and the sustainability of AI	Van Wynsberghe [33]	2021	The paper proposes a definition of sustainable AI, suggesting it involves fostering change across the entire lifecycle of AI products, from idea generation to implementation and governance, towards greater ecological integrity and social justice.
Artificial Intelligence and Business Value: a Literature Review	Enholm et al. [34]	2022	The review examines the key enablers and inhibitors of AI adoption, the various types of AI applications in organizational settings, and the first- and second-order effects of AI on business processes and firm performance.
Artificial intelligence and green product innovation: Moderating effect of organizational capital	Ying and Jin [35]	2024	The study uses a sample of Chinese A-share listed companies from 2013 to 2022 and employs a fixed-effects model to analyze the data. The findings indicate that AI positively impacts GPDI, and this impact is intensified by certain aspects of organizational capital, such as employee and board human capital, while other aspects, such as board social capital, may weaken the effect.

Table 1. *Cont.*

Research Title	Author	Publication Year	Main Findings
The impact of artificial intelligence on green innovation efficiency: Moderating role of dynamic capability	Feng et al. [36]	2024	The study utilizes a comprehensive dataset of A-share listed companies in China from 2008 to 2022, employing a novel text-based measure of AI adoption and assessing green innovation efficiency through patent applications and R&D expenditure.
The impact of artificial intelligence on green transformation of manufacturing enterprises: evidence from China	Zhang et al. [37]	2024	Artificial intelligence (AI) acts as a catalyst for the green transformation of China's manufacturing sector by enhancing management efficiency, alleviating financial constraints, and bolstering green innovation capabilities.
AI adoption rate and corporate green innovation efficiency: Evidence from Chinese energy companies	Wang et al. [38]	2024	AI adoption is significantly and positively associated with green innovation efficiency in China's energy sector, with ESG performance and long-term executive focus amplifying this relationship.
Green artificial intelligence initiatives: Potentials and challenges	Alzoubi and Mishra [5]	2024	Green AI initiatives are emerging to address the environmental impact of AI, with a focus on cloud optimization, model efficiency, and sustainability-focused AI development.
The role of artificial intelligence-enabled dynamic capability on environmental performance: The mediation effect of a data-driven culture in France and the USA	Wamba et al. [39]	2024	AI-enabled dynamic capabilities enhance environmental performance in France and the USA through the mediating effect of a data-driven culture.

2. Theoretical Background and Hypotheses

2.1. Artificial Intelligence Management and Knowledge Sharing

Artificial intelligence management refers to leveraging computational systems for logical reasoning, pattern recognition, learning, knowledge acquisition, and inferential problem-solving in decision contexts [40]. Artificial intelligence management is seen as a driver for increasing efficiency and effectiveness, automating cognitive tasks, releasing high-value work, and improving decision-making and predictive abilities [41]. Artificial intelligence management can customize targeted employee training effectively, helping them acquire the necessary professional skills quickly and thereby enhancing the level of knowledge sharing within the organization [42]. The advantages of artificial intelligence management in resource integration, opportunity identification, and supply-demand matching have disrupted traditional work environments, providing new impetus and opportunities for innovation and driving the progress of knowledge sharing [43]. Artificial intelligence management can drive knowledge sharing among employees, promote automation and integration, and facilitate knowledge exchange and interoperability among stakeholders [44]. Artificial intelligence management enables employees to have easy and round-the-clock access to knowledge, making the process of knowledge sharing highly efficient [45]. Artificial intelligence management can extract insights from a large amount of text and data, improving accessibility, promoting collaboration, and facilitating knowledge sharing [46]. Consequently, the research posits that the implementation of artificial intelligence management augments the dissemination of knowledge across organizational boundaries. Utilizing sophisticated intelligent tools and advanced algorithmic processes,

this approach facilitates enhanced accessibility and interchange of information among employees. As a result, it elevates the collective efficiency of collaboration and bolsters the entity's capacity for innovation. Based on the aforementioned theories, the study formulates the following hypotheses:

Hypothesis 1. *Artificial intelligence management positively impacts knowledge sharing.*

2.2. Artificial Intelligence Management and Green Innovation

Artificial intelligence management can create a resilient and regenerative system, keeping products, components, and materials within closed-loop systems, positively impacting green innovation while minimizing negative environmental impacts [47]. Green innovation is a behavior that involves changes in production processes, new products, and management models to reduce environmental and ecological pollution and improve energy efficiency [9]. Green innovation information is integrated into organizations to promote its application in society, enhancing the competitive advantage of related organizations [11]. Artificial intelligence management helps organizations plan resources and optimize the entire process, enabling them to address environmental issues and implement green innovation [48]. Artificial intelligence management can improve the quality of existing green products and develop new ones by controlling the production process and leveraging external green information [49]. Artificial intelligence management plays a critical role in reducing operational costs, improving worker safety, and minimizing environmental impact. Moreover, it contributes to the enhancement of green products and green innovation, leading to sustainable performance and competitive advantage [13]. For instance, Haier has leveraged artificial intelligence management to establish a user innovation platform that fosters user engagement in the product design and development process, tailored to meet their specific requirements. This approach opens up new possibilities for exploring green innovation and developing targeted products [40]. Therefore, this study posits that artificial intelligence management fortifies the innovation capacity in eco-friendly technologies and sustainable practices by refining the accuracy of decision-making and streamlining operational efficiency. Based on the aforementioned theories, the study formulates the following hypotheses:

Hypothesis 2. *Artificial intelligence management positively impacts green innovation.*

2.3. Knowledge Sharing and Green Innovation

The practical application of green innovation largely depends on employees' willingness to share and manage knowledge flows, which determines an organization's progress in achieving its green innovation goals [50]. Knowledge sharing implies an immediate investment of personal resources to disseminate information, often associated with higher short-term costs, thus reducing the overall value of sharing [51]. Knowledge sharing is considered the foundation of corporate development and transformation, playing a crucial role in fostering organizational innovation [52]. When employees actively generate and exchange knowledge among themselves, they not only deepen their understanding of environmentally friendly methods and technologies but also promote the development of green innovation [31]. Knowledge sharing helps employees recombine existing knowledge systems, apply them to current work, and create new solutions, thereby enhancing the level of green innovation [32]. Enterprises can significantly broaden their expertise and innovation capabilities by engaging in collaborative exploration with universities, research institutions, and government agencies, which is essential for unearthing eco-friendly materials, spearheading the integration of cutting-edge green technologies, and developing pioneering sustainable products [53]. Knowledge sharing fosters inter-industry collaboration and learning, thereby catalyzing green innovation through the enhancement of resource efficiency, the minimization of waste, and the embrace of clean energy practices, which in turn amplifies a company's competitive edge and propels sustainable growth [54].

The study, therefore, establishes an intrinsic link between knowledge sharing and green innovation, asserting that such sharing is pivotal for disseminating eco-friendly concepts, methodologies, and optimal practices, and in doing so, nurtures a collaborative ecosystem that is instrumental in the development of cutting-edge sustainable solutions. Based on the aforementioned theories, the study formulates the following hypotheses:

Hypothesis 3. *Knowledge sharing positively impacts green innovation.*

2.4. The Mediating Effect of Knowledge Sharing

Artificial intelligence management provides strong support for employees in solving work-related challenges and fosters their intrinsic need for knowledge sharing, contributing to the improvement of organizational-level green innovation [55]. In companies that implement artificial intelligence management, employees are more willing to engage in knowledge dissemination and sharing, increasing the likelihood of introducing market-driven products with green innovation characteristics [56]. Artificial intelligence management can accurately reduce pollution issues in production processes, enabling green innovation, which heavily relies on knowledge sharing among employees [57]. The advantage of artificial intelligence management lies in its minimal human intervention, making it easier for employees to acquire industry-specific knowledge and professional skills, reducing the cost of knowledge sharing. In today's environment emphasizing environmental consciousness, this enhances employees' awareness of green innovation [58]. Artificial intelligence management provides employees with abundant knowledge resources, resulting in an increase in their own knowledge, skills, and abilities through the application of this technology. This facilitates knowledge circulation within the organization and stimulates the implementation of green innovation [59]. Hence, the research asserts that knowledge sharing facilitates enhanced internal organizational discourse on leveraging artificial intelligence management to safeguard the environment and optimize resource allocation, subsequently sparking the emergence of innovative green initiatives and strategies. Based on the aforementioned theories, the study formulates the following hypotheses:

Hypothesis 4. *Knowledge sharing mediates the relationship between artificial intelligence management and green innovation.*

2.5. The Moderated Mediation Effects of Green Innovation

In recent years, green innovation has been recognized as a driving force for economic development, with increasing interest and rapid growth in environmental issues due to mounting environmental challenges [12]. Green innovation refers to the behavior of making changes in production processes, new products, and management models to reduce environmental and ecological pollution and improve energy efficiency [9]. The research underscores the moderating role of an innovation culture, advocating that such a culture is instrumental in amplifying the efficacy of artificial intelligence management/knowledge sharing on the front of green innovation.

Consequently, the green innovation of employees in Chinese SMEs will depend on the interaction between artificial intelligence management and knowledge sharing with innovation culture. Innovation culture can foster teamwork and exchange of ideas, facilitating the formation of knowledge sharing within the organization and making it more innovative [60]. Furthermore, organizations can establish a team-based knowledge-sharing mechanism centered around projects or goals through innovation culture. This mechanism affords individuals the chance to contribute to the genesis of proprietary organizational knowledge, simultaneously fostering an environment conducive to collaborative creation and inventiveness and enhancing the collective's capacity to disseminate and engage with shared knowledge [61]. Moreover, when the level of innovation culture within SMEs is high, organizational members' knowledge sharing and green innovation will be enhanced under the positive influence of innovation culture. Innovation culture encourages innovation by

institutionalizing key activities and further stimulates and sustains the knowledge-sharing interaction required for successful innovation by focusing on effective innovation [62]. According to social learning theory, developing an effective innovation culture that continually encourages employees to adopt new technologies can promote knowledge sharing and circulation, leading to high levels of green innovation within organizations [63]. This suggests that innovation culture has a positive impact on green innovation. Therefore, based on these theories, innovation culture not only enhances the efficiency and quality of knowledge sharing but also promotes the implementation of green innovation. By creating a work environment that encourages innovation and open communication, elevating the level of innovation culture within the organization, and promoting the widespread adoption of knowledge sharing, SMEs can cultivate employees' green innovation and environmental awareness, achieving a balance between sustainable development and social responsibility. Thus, this study posits that innovation culture within SMEs is related to artificial intelligence management.

Artificial intelligence management can effectively support green innovation by establishing cooperative partnerships among stakeholders and enabling synergistic interactions to develop differentiated, high-quality green products and services [64]. Therefore, through the application of artificial intelligence management, organizations enhance a favorable innovation environment internally, making employees more willing to exchange knowledge and skills with each other and thereby raising the level of innovation culture. Artificial intelligence management enables organizations to encourage and support internal knowledge sharing within teams in the face of rapidly changing market environments, fostering an innovative culture that encourages experimentation and fearlessness of failure [65]. Thus, artificial intelligence management, through data analysis and machine learning, can make fact-based intelligent decisions with reduced subjectivity and bias characteristics. Therefore, this study emphasizes that artificial intelligence management increases the level of innovation culture within SMEs, with a broader application of artificial intelligence management leading to higher levels of innovation culture within organizations. Artificial intelligence management can reduce unconscious biases in work, facilitate employee adaptation and mutual learning, and alleviate concerns during the process of sharing viewpoints and knowledge [66]. Furthermore, artificial intelligence management involves the intelligent transformation of enterprise pollution management patterns and technological means it dynamically collects real-time environmental information related to atmospheric, water, and soil conditions, considering environmental pressures and green innovation, which is crucial for organizations to gain a competitive advantage [67]. Therefore, artificial intelligence management also plays a significant role in enhancing internal knowledge sharing and green innovation within SMEs. Similarly, when the level of innovation culture within an organization is high, knowledge sharing and green innovation among employees will also remain at elevated levels. Moreover, when artificial intelligence management utilizes big data analysis and machine learning to better understand employee behaviors and needs, employees are more likely to perceive fair treatment, which stimulates positive work attitudes and enhances knowledge sharing and green innovation among them. Thus, if artificial intelligence management is widely applied and management can minimize human intervention to achieve a laissez-faire approach, the level of innovation culture within organizations will become stronger, and employees will be more willing to exchange knowledge and technology, leading to improved green innovation. Furthermore, this study emphasizes the interaction between artificial intelligence management, knowledge sharing, and innovation culture in determining the green innovation of employees within SMEs. In summary, the higher the level of innovation culture within SMEs, the greater the influence of artificial intelligence management and knowledge sharing on green innovation among employees. This also explains why innovation culture moderates the impact of artificial intelligence management and knowledge sharing on green innovation among employees within SMEs. In organizations with high levels of knowledge sharing, useful information is combined with like-minded individuals, allowing for the protection of the natural environment while

achieving organizational excellence. This exploration of new sustainable development paths makes products and services more characterized by green innovation [68]. Therefore, the level of green innovation among employees in SMEs depends on the level of knowledge sharing among them. In conclusion, in an organic whole, artificial intelligence management supports innovation culture by improving decision-making efficiency and fairness and encouraging employees to propose new ideas and solutions. Simultaneously, knowledge sharing plays a role in promoting team collaboration and mutual learning, highlighting the organization's commitment to the environment and inspiring employee engagement in social responsibility. Overall, the higher the level of innovation culture within Chinese SMEs, the greater the impact of artificial intelligence management and knowledge sharing on employees' green innovation.

Therefore, this study proposes knowledge sharing as a mediating variable between artificial intelligence management and green innovation. Innovation culture is set as a moderating variable between artificial intelligence management, knowledge sharing, and green innovation. Hence, this study emphasizes that innovation culture will moderate the mediating effect of knowledge sharing among employees in SMEs. Based on the aforementioned theories, the study formulates the following hypotheses:

Hypothesis 5. *Innovative culture moderates the relationship between artificial intelligence management and green innovation.*

Hypothesis 6. *Innovative culture moderates the relationship between knowledge sharing and green innovation.*

Hypothesis 7. *The mediating influence of knowledge sharing on the relationship between artificial intelligence management and green innovation is moderated by innovative culture.*

3. Methods

3.1. Sample Characteristics

The research focuses on individuals employed within the sphere of Chinese SMEs, and it gathers data through the dissemination of an online survey instrument. In regard to informed consent and data privacy, all participants in this study read the information sheet attached at the beginning of the questionnaire before participating in the research. The information sheet included a notification to participants that the study would be conducted anonymously and would not cause any inconvenience or impact to their affiliated units.

In relation to collecting data, we followed the way of snowball sampling, which involved sending our research survey to organizational members at various types of SMEs whom the all authors knew and they could send back to us. In relation to individual selection, we asked people we knew who were working in SMEs to complete the survey, and they were able to ask their colleagues to complete the survey. Overall, we conducted a survey targeting 23 SMEs in China, with a total of 346 participants. When we asked people, we knew to conduct the survey; we explained that anonymity was guaranteed during the survey to ensure the authenticity of the data, and then asked them to conduct the survey.

The information garnered throughout the research endeavor is intended solely for the fulfillment of this specific study, with a strict policy against its disclosure to any external entities. This study was investigated for 4 days from 18 April 2024 to 21 April 2024, and finally collected 346 data samples.

In this study, we conducted post hoc identification and exclusion of regular response patterns in the survey data. Regular response patterns primarily refer to respondents' answers that exhibit a certain fixed pattern or trend, such as "11111" or "12345", etc. These patterns or trends may not be based on genuine thought or experience. To prevent other data from being contaminated and to ensure the authenticity of the results, we took measures to avoid this issue [69]. After removing 15 questionnaires with responses that were too similar or had very short response times, the final number of questionnaires used

for data analysis was 331. The response rate of a questionnaire should generally not be less than 70% to be considered as a basis for research conclusions, and the final valid response rate of this study is 95.66%. Therefore, the response rate of the questionnaire in this study is within an acceptable range.

Based on the G*Power 3.1 calculations [70], a power analysis was conducted for this study. During the analytical phase, the criteria were established at a threshold of $\alpha = 0.05$, denoting statistical significance, alongside an effect size of f = 0.15, indicative of a moderate impact. The number of tested predictors was set to 1, that is, the Y variable is solely green innovation. The total number of predictors was set to 3, which includes the X variable, the mediator variable, and the moderator variable as artificial intelligence management, knowledge sharing, and innovative culture, respectively. According to the analysis results, the total sample size required to achieve a 95% statistical power level should be 89 or more. To ensure a sufficient amount of data for analysis, the final sample size applied to the analysis in this study was 331, which is significantly larger than the 89 required by the power analysis. Therefore, the sample size of this study is considered to be significantly effective and meets the level required for analysis.

In the context of the demographic profile of this study's participants, the composition was delineated as follows: 136 males (comprising 41.1% of the sample) and 195 females (accounting for 58.9%). With respect to age distribution, the study encompassed 9 participants (2.7%) in the under-20 age bracket, 83 (25.1%) within the 20–29 year range, 90 (27.2%) in the 30–39 year category, 97 (29.3%) in the 40–49 year segment, and 52 (15.7%) aged 50 or above. Educational attainment varied, with 114 (34.4%) holding technical or secondary school credentials, 104 (31.4%) possessing associate degrees, 79 (23.9%) having earned bachelor's degrees, 25 (7.6%) with master's qualifications, and 9 (2.7%) possessing doctoral degrees or higher. In terms of service duration, the survey found that 79 (24%) had been employed for less than a year, 74 (22%) for a duration of 1 to 2 years, 73 (22%) for 3 to 5 years, 32 (10%) for 5 to 7 years, and 73 (22%) for a period exceeding 7 years. Finally, in relation to the types of enterprises, the results presented that 81 participants (24.5%) were employed in the education industry, 71 (21.5%) participants were in the finance industry, 34 (10.3%) participants were in the coal mining industry, 40 (12.1%) participants were in the catering service industry, 14 (4.2%) participants were in the healthcare industry, and 91 (27.5%) in other industries.

3.2. Measurement

Artificial intelligence management encompasses the overarching strategic direction and the granular operational oversight required to govern artificial intelligence initiatives effectively [71]. For the purpose of quantifying the artificial intelligence management practices within Chinese SMEs, this research utilized a trio of metrics as articulated in the scholarly works of Chen et al. (2022) [72]. Throughout the investigative procedure of this study, the scale remained unaltered, adhering to its original scale. Sample items included "We employ an artificial intelligence system" or "We continuously update the AI system".

Knowledge sharing encompasses the acquisition of insights from the originating source as well as the dissemination of information back to it [73]. For the quantification of knowledge sharing within the ambit of Chinese SMEs, this research engaged a comprehensive seven-item scale as previously delineated in Lin's scholarly contributions from 2007 [74]. Throughout the investigative procedure of this study, the scale remained unaltered, adhering to its original scale. Sample items included "I share information I have with colleagues when they ask for it" or "I share my skills with colleagues when they ask for it".

An innovative culture is characterized by a milieu that fosters creativity, emphasizes outcome-driven initiatives, and presents an arena that encourages the embrace of challenges within the workplace [75]. In this scholarly investigation, a multifaceted scale referenced in the research by Khattak et al. (2022) has been meticulously adopted to assess the innovative culture within Chinese SMEs [76]. Throughout the investigative procedure of this study, the scale remained unaltered, adhering to its original scale. Sample items included "Our

culture encourages employees to share knowledge" or "Our culture focuses on teamwork for long-term performance".

Green innovation refers to the creation of methods, techniques, and procedures that contribute to reducing the dire outcome of production courses and products [77]. To measure Chinese SME green innovation, this study employed an eight-item scale mentioned in the studies of Wang et al. (2020) [78]. Throughout the investigative procedure of this study, the scale remained unaltered, adhering to its original scale. Sample items included "Our firm actively strengthens current green market" or "Our firm actively discovers new green market".

Participants evaluated all items on a 7-point Likert scale, indicating their level of concurrence from strong disagreement (scored 1) to strong agreement (scored 7). Therefore, based on the aforementioned variables and the PROCEE model 15, this study constructs its own model, as shown in Figure 1.

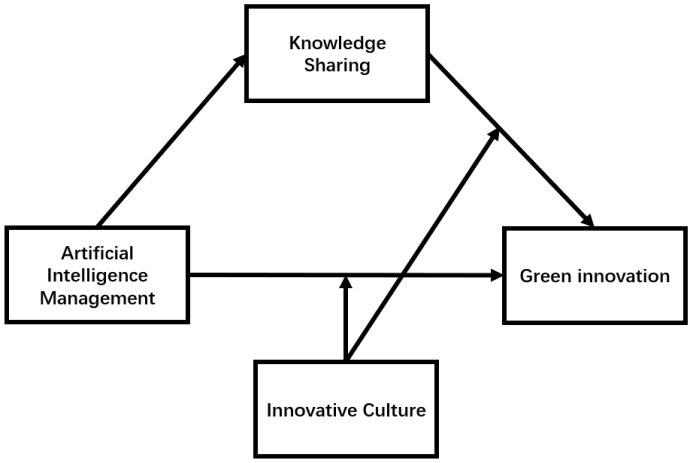


Figure 1. Research Model (Process Model 15).

3.3. Statistical Analysis

The sequential schema of statistical analyses employed in this research is delineated as follows: Initially, a demographic profiling was executed. Subsequently, a confirmatory factor analysis (CFA) was undertaken to validate the factorial structure. This was followed by an assessment of the measurement instrument's reliability. Thereafter, an examination of the variables' descriptive statistics and their intercorrelations was performed. Culminating the analysis, the hypotheses were rigorously tested. For the demographic analysis, reliability evaluation, computation of descriptive statistics, correlation analysis, and moderation effects, the study leveraged SPSS version 26.0. Furthermore, the CFA and path analysis relied on AMOS version 23.0. Ultimately, the moderated mediation model was scrutinized employing SPSS PROCESS Macro v4.2, Model 15.

4. Results

4.1. Confirmatory Factor Analysis

Confirmatory factor analysis is utilized to ascertain the structural integrity and dimensional consistency of the latent constructs under investigation [79]. Employing AMOS version 23.0 for confirmatory factor analysis (CFA), this study sequentially evaluated six distinct models to ascertain their fit indices, commencing with an anticipated model where four constructs were independently loaded in a simultaneous manner. The statistical outcomes for this model were as follows: $\chi^2(p) = 803.173$ ($p < 0.000$), $\chi^2/df = 3.077$, RMSEA = 0.079, IFI = 0.902, CFI = 0.901, PNFI = 0.788, PGFI = 0.658. Model 2, which assumed a single-factor structure encompassing all items, yielded less favorable results: $\chi^2(p) = 1459.493$ ($p < 0.000$), $\chi^2/df = 5.528$, RMSEA = 0.117, IFI = 0.856, CFI = 0.855, PNFI = 0.730, PGFI = 0.592. Model 3, which amalgamated artificial intelligence management with knowledge sharing as

Factor 1 and innovative culture with green innovation as Factor 2, exhibited the following statistics: $\chi^2(p)$ = 1349.475 ($p < 0.000$), χ^2/df = 5.112, RMSEA = 0.112, IFI = 0.869, CFI = 0.868, PNFI = 0.741, PGFI = 0.601. Model 4, alternatively, grouped artificial intelligence management with innovative culture as Factor 1 and green innovation with knowledge sharing as Factor 2, presenting statistics of $\chi^2(p)$ = 1399.67 ($p < 0.000$), χ^2/df = 5.302, RMSEA = 0.114, IFI = 0.863, CFI = 0.862, PNFI = 0.736, and PGFI = 0.592. Model 5, dividing the variables into three factors—artificial intelligence management, green innovation, and a combination of knowledge sharing and innovative culture—demonstrated improved fit indices: $\chi^2(p)$ = 862.001 ($p < 0.000$), χ^2/df = 3.278, RMSEA = 0.083, IFI = 0.928, CFI = 0.927, PNFI = 0.788, PGFI = 0.659. On the contrary, Model 6, which combined innovative culture and green innovation into Factor 1, designated artificial intelligence management as Factor 2, and categorized knowledge sharing as Factor 3, disclosed $\chi^2(p)$ = 1253.306 ($p < 0.000$), χ^2/df = 4.765, RMSEA = 0.107, IFI = 0.880, CFI = 0.880, PNFI = 0.748, and PGFI = 0.609. After meticulous examination of these outcomes, it was deduced that Model 1 corresponds most fittingly with the data, signifying a substantial fit. An exhaustive roundup of the fit indices for each structural model is encapsulated in Table 2.

Table 2. Summary of structural model fit results.

Model	$\chi^2(p)$	χ^2/df	RMSEA	IFI	CFI	PNFI	PGFI
Model 1 (Expected Model of four-factor [a])	803.173 (0.000)	3.077	0.079	0.935	0.934	0.788	0.658
Model 2 (one-factor [b])	1459.493 (0.000)	5.528	0.117	0.856	0.855	0.730	0.592
Model 3 (two-factor [c])	1349.475 (0.000)	5.112	0.112	0.869	0.868	0.741	0.601
Model 4 (two-factor [d])	1399.67 (0.000)	5.302	0.114	0.863	0.862	0.736	0.592
Model 5 (three-factor [e])	862.001 (0.000)	3.278	0.083	0.928	0.927	0.788	0.659
Model 6 (three-factor [f])	1253.306 (0.000)	4.765	0.107	0.880	0.880	0.748	0.609

Note: [a] = Artificial intelligence management, knowledge sharing, innovative culture, and green innovation. [b] = All items were loaded on a single factor. [c] = Artificial intelligence management and knowledge sharing, innovative culture and green innovation. [d] = Artificial intelligence management and innovative culture, knowledge sharing and green innovation. [e] = Artificial intelligence management, green innovation, knowledge sharing and innovative culture. [f] = Innovative culture, green innovation, artificial intelligence management and knowledge sharing.

Model 1's CFA, suggesting a four-factor solution, showed a superior model fit, validating the construct validity. For convergent validity assessment, the standardized regression coefficients for AI management were within the range of 0.763 to 0.949; for knowledge sharing, they were between 0.690 and 0.813; innovative culture had values from 0.775 to 0.821; and for green innovation, the range was 0.758 to 0.834. These coefficients reflect a substantial convergence towards the theoretical constructs. Furthermore, the assessment of AVE and CR confirmed the measurements' reliability. The AVE values were 0.747 for AI management, 0.607 for knowledge sharing, 0.631 for innovative culture, and 0.638 for green innovation—each exceeding the 0.5 threshold. The CR values were 0.812 for AI management, 0.873 for knowledge sharing, 0.874 for innovative culture, and 0.896 for green innovation, all surpassing the 0.7 threshold and indicating a high level of reliability. In the overall evaluation of model fit, indices from three categories were reviewed: absolute fit, incremental fit, and parsimonious adjusted fit. The absolute fit indices were $\chi^2(p)$ = 803.173 ($p < 0.000$), χ^2/df = 3.077, and RMSEA = 0.079. The incremental fit indices were IFI = 0.935 and CFI = 0.934. The parsimonious adjusted indices were PNFI = 0.788 and PGFI = 0.658. Together, these indices confirmed the CFA's acceptability. As a result, the structural equa-

tion model was considered significant, with Table 3 providing details on the convergent validity results. This analysis affirms the model's robustness and the importance of the relationships proposed within the study's theoretical framework.

Table 3. The Result of Confirmatory Factor Analysis.

Variables		Estimate	S.E.	C.R.	*p*	Standardized Regression Weights	AVE	C.R
Artificial Intelligence Management (A)	A3	1				0.763	0.747	0.812
	A2	1.305	0.044	29.809	***	0.949		
	A1	1.406	0.055	25.434	***	0.871		
Knowledge Sharing (B)	B1	1				0.804	0.607	0.873
	B2	0.977	0.043	22.653	***	0.785		
	B3	0.956	0.048	20.054	***	0.759		
	B4	0.857	0.05	16.988	***	0.69		
	B5	1.062	0.047	22.376	***	0.803		
	B6	1.002	0.044	22.975	***	0.813		
	B7	0.96	0.044	21.949	***	0.794		
Innovative Culture (C)	C7	1				0.789	0.631	0.874
	C6	1.063	0.04	26.873	***	0.821		
	C5	1.107	0.052	21.214	***	0.775		
	C4	1.067	0.049	21.763	***	0.786		
	C3	1.013	0.046	22.159	***	0.787		
	C2	0.982	0.045	21.772	***	0.789		
	C1	1.05	0.045	23.344	***	0.815		
Green Innovation (D)	D1	1				0.801	0.638	0.896
	D2	1.063	0.044	24.329	***	0.834		
	D3	1.024	0.043	23.785	***	0.829		
	D4	0.954	0.048	19.801	***	0.758		
	D5	0.966	0.048	20.199	***	0.762		
	D6	1.097	0.047	23.182	***	0.817		
	D7	1.027	0.048	21.382	***	0.788		
	D8	1.03	0.047	21.917	***	0.799		
Model Fit Index	$\chi^2(p)$= 803.173 (0.000), χ^2/df = 3.077, RMSEA = 0.079, IFI = 0.935, CFI = 0.934, PGFI = 0.658, PNFI = 0.788							

***: $p < 0.001$.

4.2. Reliability Analysis

Reliability analysis assesses the scale's internal consistency, indicating how well each item measures the underlying construct's intended variance [80]. Thus, this study relied on Cronbach's alpha to validate the reliability of the variables under investigation. The outcomes of the reliability analysis are concisely outlined below. Initially, the assessment of artificial intelligence management, comprising three items, was conducted using a 7-point Likert scale to measure the participants' acknowledgment of artificial intelligence management. The Cronbach's alpha for this scale was determined to be 0.927. Subsequently, the variable of employees' knowledge sharing was evaluated through seven items on a 7-point Likert scale, which were designed to measure the level of knowledge sharing among participants within their professional environment. The Cronbach's alpha value for this

variable was recorded at 0.929. Thirdly, the innovative culture was gauged through seven items on a 7-point Likert scale, which aimed to evaluate the participants' exposure to and engagement with an innovative culture. The Cronbach's alpha for this dimension was 0.938. Fourthly, green innovation was explored with eight items on the same 7-point scale, capturing the participants' involvement and contribution to green innovation practices. The Cronbach's alpha for this aspect was found to be 0.946. Each Cronbach's alpha coefficient exceeded the threshold of 0.7, indicating that the reliability of the variables was both substantial and valid. Table 4 presents the findings from the reliability analysis.

Table 4. Reliability analysis results.

Variables	Item	Cronbach's Alpha
Artificial Intelligence Management (A)	1. We employ an artificial intelligence system.	0.927
	2. We continuously monitor the progress of the AI system.	
	3. We continuously update the AI system.	
Knowledge Sharing (B)	1. When I have learned something new, I tell my colleagues about it.	0.929
	2. When they have learned something new, my colleagues tell me about it.	
	3. Knowledge sharing among colleagues is considered normal in my company.	
	4. I share information I have with colleagues when they ask for it.	
	5. I share my skills with colleagues when they ask for it.	
	6. Colleagues in my company share knowledge with me when I ask them to.	
	7. Colleagues in my company share their skills with me when I ask them to.	
Innovative Culture (C)	1. Our flexible structure facilitates searching for and incorporating diverse points of view.	0.938
	2. Our culture rewards behaviors that relate to creativity and innovation.	
	3. Our organization's culture encourages informal meetings and interactions.	
	4. Our culture encourages employees to monitor their own performance.	
	5. Employees take risks by continuously experimenting with new ways of doing things.	
	6. Our culture encourages employees to share knowledge.	
	7. Our culture focuses on teamwork for long-term performance.	
Green Innovation (D)	1. Our firm actively improves current green products, processes and services.	0.946
	2. Our firm actively adjusts current green products, processes and services.	
	3. Our firm actively strengthens current green market.	
	4. Our firm actively strengthens current green technology.	
	5. Our firm actively adopts new green products, processes and services.	
	6. Our firm actively exploits new green products, processes and services.	
	7. Our firm actively discovers new green market.	
	8. Our firm actively enters new green technology.	

4.3. Descriptive Statistics and Correlation Analysis

Table 5 presents the results of the descriptive statistics and correlation analysis, detailing both the average values and standard deviations for the study's variables. The average scores for the dimensions of artificial intelligence management, knowledge sharing, innovative culture, and green innovation were recorded as 5.434, 5.559, 5.462, and 5.543, respectively. Correspondingly, the standard deviations for these constructs were 1.537, 1.116, 1.189, and 1.162, respectively.

Table 5. The Results of Descriptive Statistics and Correlation Analysis.

	Mean	S.D	Artificial Intelligence Management	Knowledge Sharing	Innovative Culture	Green Innovation
Artificial Intelligence Management	5.4340	1.53761	-			
Knowledge Sharing	5.5598	1.11638	0.641 ***	-		
Innovative Culture	5.4627	1.18968	0.673 ***	0.870 ***	-	
Green Innovation	5.5438	1.16204	0.620 ***	0.829 ***	0.858 ***	-

***: $p < 0.001$.

To establish the relationships between the variables, this research performed a correlational analysis. The correlation analysis yielded the following outcomes: Artificial intelligence management correlated positively with knowledge sharing ($r = 0.641$, $p < 0.001$), innovative culture ($r = 0.673$, $p < 0.001$), and green innovation ($r = 0.620$, $p < 0.001$). There was also a positive correlation between knowledge sharing and innovative culture ($r = 0.870$, $p < 0.001$), as well as between knowledge sharing and green innovation ($r = 0.829$, $p < 0.001$). Furthermore, innovative culture correlated positively with green innovation ($r = 0.858$, $p < 0.001$).

In this study, all correlations are positive, suggesting that as one variable increases, the other also tends to increase. The correlation between artificial intelligence management and knowledge sharing ($r = 0.614$) is considered a large effect size according. This indicates a strong relationship, suggesting that companies that effectively manage artificial intelligence also tend to have more extensive knowledge sharing practices. The relationship between artificial intelligence management and innovative culture ($r = 0.673$) also represents a large effect size. This correlation implies that a robust artificial intelligence management strategy is closely linked to a strong innovative culture within an organization. The correlation between artificial intelligence management and green innovation ($r = 0.620$) is similarly large, indicating that companies with advanced artificial intelligence management are more likely to engage in green innovation activities. Knowledge sharing and innovative culture have an extremely large correlation ($r = 0.870$), which is one of the highest effect sizes observed in this study. This suggests that a culture that encourages innovation is highly dependent on the presence of effective knowledge sharing mechanisms. The correlation between knowledge sharing and green innovation ($r = 0.829$) is also very large, indicating that when employees actively share knowledge, it significantly promotes the development of green innovations. Lastly, the relationship between innovative culture and green innovation ($r = 0.858$) is similarly very large, reinforcing the idea that a culture of innovation is a key driver of green innovation initiatives.

4.4. Hypothesis Test

A total of seven hypotheses were formulated for this study. Firstly, the study confirmed the impact of artificial intelligence management on employees' engagement in knowledge sharing. Subsequently, the study assessed the influence of artificial intelligence management on their propensity for green innovation. Thirdly, the research evaluated the role of knowledge sharing in fostering employees' green innovation efforts. Fourth, the study investigated whether employees' knowledge sharing serves as a mediator in the link between artificial intelligence management and green innovation. In order to test the hypotheses mentioned above, this study conducted path analysis using Amos ver. 23.0. The outcomes of the analysis are depicted in Table 6.

Table 6. The results of path analysis.

Path			Estimate	S.E.	C.R.	*p*
Artificial Intelligence Management	→	Knowledge Sharing	0.577	0.047	12.294	***
Artificial Intelligence Management	→	Green Innovation	0.808	0.062	13.121	***
Knowledge Sharing	→	Green Innovation	0.096	0.041	2.341	0.019
Indirect Effect			Effect	Boot LLCI	Boot ULCI	
Artificial Intelligence Management → Knowledge Sharing → Green Innovation			0.003	0.043	0.690	
Model Fit Index	$\chi^2(p)$ = 370.444 (0.000), χ^2/df = 3.062, RMSEA = 0.079, IFI = 0.956, CFI = 0.955, PGFI = 0.626, PNFI = 0.74					

***: $p < 0.001$.

Hypothesis 1 posited a positive relationship between artificial intelligence management and knowledge sharing, which was confirmed with a substantial effect size ($\beta = 0.577$, $p < 0.001$). Consequently, Hypothesis 1 was validated, indicating that effective artificial intelligence management can indeed stimulate employees to share knowledge.

Hypothesis 2 established that artificial intelligence management positively influenced employees' green innovation. Artificial intelligence management had a significant positive influence on employees' green innovation (estimate = 0.808, $p < 0.001$). Consequently, Hypothesis 2 is confirmed, and these findings elucidate the reason why artificial intelligence management fosters employee engagement in green innovation.

Hypothesis 3 established that knowledge sharing positively influenced employees' green innovation. Knowledge sharing had a significant positive influence on employees' green innovation (estimate = 0.096, $p < 0.05$). As a result, Hypothesis 3 received validation, indicating that artificial intelligence management stimulates employees to participate in green innovation initiatives.

Hypothesis 4 investigated whether employees' knowledge sharing mediates the impact of artificial intelligence management on green innovation. The mediating role of knowledge sharing was quantified with an indirect effect size of 0.003, and the 95% confidence interval ranged from 0.043 to 0.690. Given that zero was not found within the Bootstrap LLCI and Boot ULCI, the mediating effect was deemed statistically significant. Consequently, Hypothesis 4 was confirmed.

Hypotheses 5 and 6 explored the potential moderating influence of innovative culture on the associations among artificial intelligence management, knowledge sharing, and green innovation. To assess these hypotheses, a multiple regression analysis was performed using SPSS version 26.0.

Hypothesis 5 proposed that innovative culture plays a moderating role in the relationship between artificial intelligence management and green innovation. The analysis revealed that innovative culture indeed significantly influenced this relationship ($\beta = 0.056$, $p < 0.1$), thus supporting Hypothesis 5. This finding indicates that when innovative culture is strong, the positive impact of artificial intelligence management on green innovation is amplified. Table 7 details the moderation analysis outcomes, while Figure 2 visually represents the interaction, highlighting how higher perceptions of innovative culture correspond to increased green innovation, particularly when artificial intelligence management is highly regarded.

Table 7. The Result of Moderation (artificial intelligence management).

Dependent Variable: Green Innovation							
	Model 1		**Model 2**		**Model 3**		
	β	***t***	***β***	***t***	***β***	***t***	**VIF**
Artificial Intelligence Management (A)	0.620 ***	14.350	0.079 *	2.063	0.092 *	2.373	1.902
Innovative Culture (B)			0.805 ***	21.151	0.821 ***	21.028	1.935
Interaction (A × B)					0.056 †	1.735	1.303
R^2 (Adjusted R^2)	0.385 (0.383)		0.740 (0.738)		0.742 (0.740)		
ΔR^2 (ΔAdjusted R^2)	-		0.355 (0.355)		0.002 (0.002)		
F	205.910 ***		466.335 ***		313.801 ***		

***: $p < 0.001$, *: $p < 0.05$, † = $p < 0.1$.

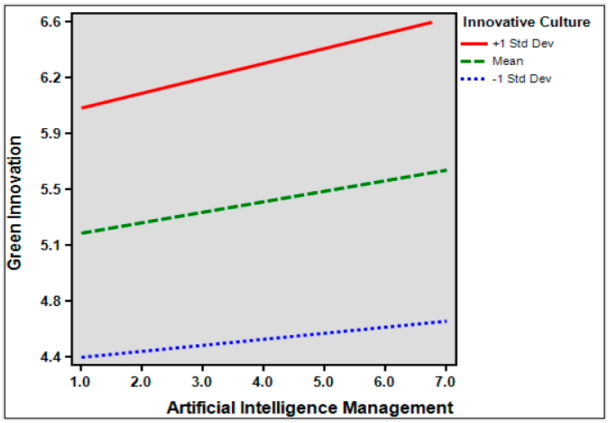


Figure 2. The moderating effect of innovative culture (artificial intelligence management).

Hypothesis 6 posited that innovative culture would moderate the impact of knowledge sharing on green innovation. The data analysis confirmed this hypothesis, demonstrating that innovative culture substantially moderated the relationship between knowledge sharing and green innovation ($\beta = 0.130$, $p < 0.001$). This outcome underscores the synergistic role of knowledge sharing and innovative culture in fostering green innovation. Table 8 presents the detailed moderation effects, and Figure 3 illustrates the interaction, clarifying that heightened levels of innovative culture are linked to increased green innovation, especially when knowledge sharing is prevalent.

Table 8. The Result of Moderation (knowledge sharing).

Dependent Variable: Green Innovation							
	Model 1		**Model 2**		**Model 3**		
	β	***t***	***β***	***t***	***β***	***t***	**VIF**
Knowledge Sharing (A)	0.829 ***	26.871	0.338 ***	6.219	0.396 ***	7.251	4.378
Innovative Culture (B)			0.564 ***	10.368	0.571 ***	10.771	4.119
Interaction (A × B)					0.130 ***	4.329	1.321
R^2 (Adjusted R^2)	0.687 (0.686)		0.764 (0.763)		0.777 (0.775)		
ΔR^2 (ΔAdjusted R^2)	-		0.077 (0.077)		0.013 (0.012)		
F	722.035 ***		531.626 ***		379.839 ***		

***: $p < 0.001$.

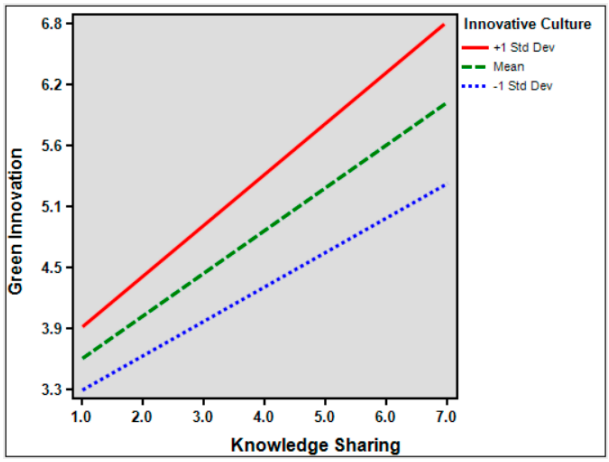


Figure 3. The moderating effect of innovative culture (knowledge sharing).

Table 9 delineates the moderated mediation impact of innovative culture. At one standard deviation below the mean, the indirect effect was 0.1380 with a bootstrap standard error of 0.0562, and the 95% confidence interval ranged from 0.0363 to 0.2569. At the mean level, the indirect effect was 0.1918, accompanied by a bootstrap standard error of 0.0492, with the confidence interval spanning from 0.1086 to 0.2971. At one standard deviation above the mean, the indirect effect was 0.2457, with a bootstrap standard error of 0.0622, and the confidence interval extended from 0.1357 to 0.3761. The absence of zero in the confidence intervals at all three levels indicates statistical significance for the moderation effect. Additionally, the index of moderated mediation was 0.0453, with a bootstrap standard error of 0.0279 and a 95% confidence interval from 0.0005 to 0.1028, confirming the significance of the bootstrapped confidence interval. Collectively, these findings substantiate the significant moderated mediation role of innovative culture, thereby validating Hypothesis 7.

Table 9. The moderated mediation effect of innovative culture.

Dependent Variable: Green Innovation					
Moderator	**Level**	**Conditional Indirect Effect**	**Boot SE**	**Boot LLCI**	**Boot ULCI**
Innovative Culture	−1 SD (−1.1897)	0.1380	0.0562	0.0363	0.2569
	M	0.1918	0.0492	0.1086	0.2971
	+1 SD (+1.1897)	0.2457	0.0622	0.1357	0.3761
Index of moderated mediation					
	Index		Boot SE	Boot LLCI	Boot ULCI
	0.0453		0.0279	0.0005	0.1028

4.5. Sensitivity Analysis

To assess the robustness of the moderated mediation model, this study conducted a sensitivity analysis. The initial model included the independent variable artificial intelligence management, the mediator variable knowledge sharing, the moderator variable innovative culture, and the dependent variable green innovation. First, the base model was tested, yielding the following results: The impact of artificial intelligence management on green innovation: $\beta = 0.0347$, $p > 0.1$; the impact of knowledge sharing: $\beta = 0.4121$, $p < 0.001$; the impact of innovative culture: $\beta = 0.5218$, $p < 0.001$.

Second, the sample with moderator variables greater than 5.4627 (176 cases) was tested, producing the following outcomes: The impact of artificial intelligence management on green innovation: $\beta = 0.0577$, $p < 0.1$; the impact of knowledge sharing: $\beta = 0.4858$, $p < 0.001$; the impact of innovative culture: $\beta = 0.4351$, $p < 0.001$.

Lastly, the sample with moderator variables less than 5.4627 (155 cases) was examined, with the following results: The impact of artificial intelligence management on green innovation: $\beta = 0.0263$, $p > 0.1$; the impact of knowledge sharing: $\beta = 0.3933$, $p < 0.001$; the impact of innovative culture: $\beta = 0.6319$, $p < 0.001$. The above findings indicate that the model's robustness is consistent across different specifications. The results are presented in Table 10.

Table 10. The Sensitivity Analysis of Moderated Mediation Model Parameters.

Model Adjustment	X → Y(β)	M(β)	W(β)	R^2	p
Initial Model	0.0347	0.4121	0.5218	0.7803	0.0000
W > 5.4627	0.0577	0.4858	0.4351	0.6494	0.0000
W < 5.4627	0.0263	0.3933	0.6319	0.5988	0.0000

5. Discussion

This study specifically explores the relationship between artificial intelligence management and green behavior for organizational sustainable outcomes. In the relationship between artificial intelligence management and green behavior, the mediating role of knowledge sharing is examined. Furthermore, through the moderated mediation model, it is verified whether the path from artificial intelligence management/knowledge sharing to green innovation depends on the level of innovation culture. These findings provide insights for future research and sustainable development in Chinese SMEs, indicating the direction of their growth. Therefore, the conclusions drawn from this study are summarized as follows:

5.1. Theoretical Implications

Firstly, knowledge sharing has a partial mediating effect between artificial intelligence management and employees' green innovation. This indicates that artificial intelligence management can directly impact green innovation and also indirectly influence it through employees' knowledge sharing. The application of artificial intelligence management in production enables the development of products practicing circular economy, leading to a more successful reduction of environmental impact, cost reduction, and promotion of employees' green innovation capabilities [47]. Artificial intelligence management, as a new form of management, possesses the capability to rapidly process and analyze large amounts of data, assisting employees in better utilization and sharing of this knowledge. Moreover, through artificial intelligence management, employees are able to gather, organize, and analyze various forms of knowledge more effectively, leading to more accurate decision-making and strategic planning. Furthermore, artificial intelligence management can predict future development directions based on historical data and trends, helping employees make wiser choices. Therefore, artificial intelligence management can facilitate knowledge accumulation, dissemination, and cross-departmental cooperation. By building intelligent management platforms, managers and employees can share the latest green technologies, case experiences, and industry insights, inspiring innovative thinking and accelerating the implementation and promotion of green innovation. Hence, this implies that knowledge sharing can partially mediate the relationship between artificial intelligence management and green innovation. Moreover, a high level of green innovation is an inevitable source that can promote organizational sustainable outcomes.

Secondly, innovation culture has a moderating effect between artificial intelligence management and knowledge sharing. In the correlation analysis, there is a positively (+) correlation between artificial intelligence management and knowledge sharing, a positively

(+) correlation between artificial intelligence management and innovation culture, and a positively (+) correlation between innovation culture and knowledge sharing. Furthermore, the results presented in Table 7 and depicted in Figure 2 indicate that the interaction effect between artificial intelligence management and innovation culture is significantly robust. Organizations lacking an innovation culture will find that knowledge sharing is restricted, as the organization needs to provide necessary knowledge for employees to learn and enhance their innovative thinking [81]. Once top-level managers support the value of knowledge, encourage employees to share knowledge with each other to solve problems and collectively create new knowledge [82]. Therefore, this indicates that regardless of whether the moderating effect of innovation culture is at a high or low level, its interaction with artificial intelligence management will enhance employees' knowledge sharing, with higher levels of innovation culture showing greater effects than lower levels. Hence, by promoting innovative thinking and open communication, artificial intelligence management encourages employees to actively share professional knowledge and experiences. This nurturing cultural ambiance fosters an atmosphere of reassurance and self-assurance among staff, subsequently igniting their fervor to participate actively in the realms of knowledge dissemination, collaborative problem resolution, and the co-genesis of innovative concepts. With the promotion of such a culture, collaboration and cooperation among team members are strengthened, thus driving green innovation and development.

Thirdly, innovation culture has a moderating effect between knowledge sharing and green innovation. In the correlation analysis, there is a positive (+) correlation between knowledge sharing, innovation culture, and green innovation. Consequently, the data portrayed in Table 8 and illustrated in Figure 3 underscore the substantial and noteworthy interactive impact of knowledge sharing and innovation culture. Encouraging collaboration and knowledge sharing among stakeholders and nurturing partnerships with suppliers, customers, and research institutions accelerates the adoption and integration of green innovation in the innovation process [83]. Green innovation can be incentivized through re-designing processes to enhance manufacturing and operational environmental efficiency, thereby improving environmental sustainability [12]. Therefore, this indicates that regardless of whether the moderating effect of innovation culture is at a high or low level, its interaction with knowledge sharing will enhance employees' green innovation, with higher levels of innovation culture showing greater effects than lower levels. Hence, through knowledge sharing, different stakeholders can pool their expertise and experiences, promoting communication and cooperation. This open communication and information flow stimulate innovative thinking and provide more possibilities for the adoption and integration of green technologies. In this atmosphere of collaboration and knowledge exchange, innovation culture is nurtured and strengthened, enabling organizations to better focus on sustainability goals and effectively drive the implementation and development of green innovation.

Fourthly, to verify whether innovation culture can moderate the mediating effect of knowledge sharing, this study examined the moderated mediation effect of innovation culture. The results indicate that innovation culture has a significant moderated mediation effect. This finding aligns with the expected results. Innovation culture motivates organizational members to be more open and inclusive, encouraging them to share knowledge and insights in the fields of artificial intelligence management and green innovation. This knowledge sharing not only drives the application of artificial intelligence technology in green innovation but also promotes collaboration and communication among interdisciplinary teams. The positive impact of innovation culture makes organizations more focused on sustainable development and accelerates the pace of promoting green innovation. Therefore, innovation culture plays a bridging role between artificial intelligence management and green innovation, providing strong support for knowledge sharing and driving the synergistic development between the two. To validate the moderated mediation effect of innovation culture, this study employed a more comprehensive approach to stimulate

green innovation, laying the foundation for future exploration or identification of more effective methods to activate green innovation.

Beyond the theoretical perspectives previously discussed, the results of this study regarding the positive impact of artificial intelligence management on green innovation are consistent with the findings of Almansour et al. (2024) [30]. Furthermore, this study also confirms the positive influence of artificial intelligence management on employee knowledge sharing, as well as the positive impact of knowledge sharing on employee green innovation. Lastly, this study verifies both the mediating effect of knowledge sharing and the moderated mediation effect of innovation culture.

5.2. Practical Implication

Firstly, it can be affirmed that artificial intelligence management is being applied within Chinese SMEs. Moreover, according to the results of this study, it is confirmed that artificial intelligence management plays a positive role in enhancing employee knowledge sharing and green innovation. A recent study by MIT Sloan Management Review found that over 80% of organizations view artificial intelligence management as a strategic opportunity, and almost 85% of organizations believe that it is a pathway to gaining competitive advantage [84]. Therefore, the management within enterprises or organizations should pay full attention to the positive effects and benefits of artificial intelligence management for employees. Furthermore, the application of artificial intelligence management can assist businesses in data analysis, decision-making, and process optimization, thereby improving efficiency, reducing costs, and achieving innovation. Through artificial intelligence technology, employees are able to accurately predict market trends, optimize supply chain management, and enhance customer experience. Hence, to enhance the level of artificial intelligence management in Chinese SMEs, relevant training courses on artificial intelligence should be provided to help employees understand the concepts, applications, and best practices of artificial intelligence. It is also necessary to ensure the soundness of supervision and evaluation mechanisms for artificial intelligence systems, enabling timely adjustments and optimization of system performance.

Secondly, in conjunction with the theoretical perspectives previously delineated, the empirical findings of this study collectively suggest that the exchange of knowledge among staff members is also a pivotal determinant in fostering green innovation. Knowledge sharing can promote teamwork and communication, accelerate problem-solving, enhance employee learning and development, and stimulate innovation and improvement within organizations. It is projected that corporations featured in the Fortune 500 list incur losses exceeding $31.5 billion per annum as a consequence of ineffective knowledge sharing initiatives [51]. Therefore, to enhance the level of green innovation among employees in Chinese SMEs, measures such as establishing knowledge sharing platforms, implementing reward mechanisms, conducting training and sharing conferences, fostering cross-departmental collaboration, and sharing successful case studies can be adopted to encourage employees to share environmental innovation concepts, technologies, and experiences. This will facilitate the dissemination and application of green innovation thinking throughout the organization.

Thirdly, the construction of an innovative culture in Chinese SMEs. Innovation culture plays a significant role within organizations. It not only stimulates employees' creativity and imagination but also enhances their engagement and team cohesion, thereby fostering the emergence of new ideas and solutions and strengthening the competitive advantage of enterprises. The primary focus of an innovation culture lies in the internal system of an organization and maintaining an open attitude towards new ideas to stay ahead of competitors [85]. Therefore, to enhance the level of green innovation among employees in Chinese SMEs, the application of an innovative culture is crucial. Organizations can encourage employees to actively propose environmentally friendly innovation projects and suggestions, making them aware of the importance of their contributions to environmental causes. Additionally, establishing reward mechanisms to incentivize green innovation,

such as providing bonuses, promotion opportunities, or other incentives to recognize environmental innovators, is essential.

Fourthly, promoting the application of green innovation in SMEs. Including strategies related to green innovation in the organizational strategy would be beneficial for future implementation of green innovation practices and establishing industry advantages [27]. The green innovation of employees in SMEs plays a vital role in China's energy conservation and emission reduction development. Cultivating employees' green awareness and inspiring their enthusiasm for participating in green innovation will help create a favorable internal environment within the company and facilitate the implementation of green innovation concepts. Furthermore, the green innovation of employees in SMEs not only enhances the competitiveness and sustainability of the businesses but also influences broader social groups, encouraging more people to actively engage in environmental causes. The green innovation behavior of employees will also have a demonstration effect within and outside the company, promoting improvements in the overall ecological environment of the industry. This contribution enables SMEs to contribute to the development of a beautiful China and achieve green and low-carbon development goals in China's energy conservation and emission reduction efforts.

Fifthly, in China, SMEs can achieve sustainable development by drawing on the research of D'Adamo and colleagues [86]. This study utilized Multi-Criteria Decision Analysis (MCDA) and cluster analysis to compare the performance of Italian regions in 2022 based on 105 indicators associated with the Equitable and Sustainable Well-being (BES) framework and 139 indicators related to the sustainable development goals (SDGs). The results showed that Lombardy performed best at the SDG level while the provinces of Trento and Bolzano led at the BES level. This finding emphasizes that a comprehensive innovation model, regional cooperation, and synergy between regional specificities can generate competitive advantages, especially when combined with resources and skills with an international outlook. Chinese SMEs can adopt a similar comprehensive approach, using artificial intelligence management to promote green innovation and achieve sustainable development goals (SDGs). By employing advanced data analysis and decision support systems, SMEs can more effectively monitor their environmental impact, optimize resource allocation, and enhance the sustainability of their operations.

Sixthly, how can SMEs in China achieve sustainable development? Chinese SMEs are instrumental in driving sustainable development through strategic adoption of green practices, which are not only eco-friendly but also resonate with consumer preferences for sustainability. This aligns with the findings of Chege and Wang (2020), who emphasize the role of technology innovation in enhancing SME performance through environmental sustainability practices [87]. The integration of digital technologies can provide SMEs with tools to optimize resource use and improve operational efficiency, crucial for long-term viability in a competitive landscape. Furthermore, sustainable packaging and transportation practices, as reviewed systematically by Jones et al. (2021), significantly reduce the carbon footprint and enhance the appeal to sustainability-focused consumers and investors [88]. By embracing these measures, Chinese SMEs can contribute to the country's broader sustainability goals, including the ambitious double-carbon targets set by the Chinese government, and ensure their own growth and resilience amidst environmental and economic challenges [89].

5.3. Limitations and Future Research

Despite making valuable contributions to the verification of the relationship between knowledge sharing and the impact on artificial intelligence management and green innovation, as well as providing noteworthy insights into the moderated mediation aspect of innovation culture, this study also has certain limitations, which are outlined below:

Firstly, regarding the issues identified during the data validation process. This study found unsatisfactory results in terms of discriminant validity and common method bias. Therefore, in future research, we will consider increasing the sample size to ensure sufficient

representativeness of the data. Additionally, longitudinal studies will be conducted to continuously collect data, validate the stability and consistency of the research findings, as well as further explore the relationships between variables.

Secondly, this study only focused on artificial intelligence management for research and analysis. Similarly, green organizational identity [29] and organizational change [12] have significance in driving green innovation. If environmental concerns become mainstream in green organizational identity, they can be seen as having positive implications that encourage organizational members to invest more effort in environmental activities [29]. Therefore, in future research, attention will be given to studying other independent variables with positive influences. Moreover, by comparing the results with the findings of this study, we can identify differences in the presence of various positive impacting independent variables.

Thirdly, this study only considered green innovation as the dependent variable for research. However, it is equally worth studying and paying attention to green innovation as a moderating variable. For instance, Khan et al. (2022) conducted a study encompassing 67 enterprises across five continents—encompassing Europe, Australia and New Zealand, Asia, North America, and Africa—where green innovation was posited as a moderating factor [90]. Their research results revealed that green innovation can have a moderating effect between sustainable development goals and corporate financial performance [90].

Fourthly, this study only conducted empirical research on SMEs within China. Considering geographical locations and cultural differences, in the future, we will conduct empirical research on employees of SMEs in some European and American countries with significant cultural differences from China. This approach can explore whether similar results are obtained when conducting empirical analyses on organizational members from different countries and cultural backgrounds, which holds important research significance [91]. By comparing the findings with the results of this study, we can further investigate the existing differences in various aspects.

Fifthly, when considering the external validity of this study, we acknowledge that our sample primarily consists of employees from small and medium-sized enterprises across 23 provinces and regions within China. This may limit our ability to generalize the results to other populations. Nonetheless, our research design aims to mimic real-world scenarios, which may aid in enhancing the generalizability of our findings. Future studies should consider conducting research with more diverse samples and across various geographical areas to further validate the generalizability of these results.

Sixthly, the results of this study show that artificial intelligence management has a significant positive impact on green innovation ($\beta = 0.808$, $p < 0.001$). This finding is of great importance for promoting environmental sustainability, as it indicates that by optimizing artificial intelligence management, companies can develop more environmentally friendly products and services. Moreover, this kind of innovation may reduce dependence on natural resources, decrease waste production, and improve energy efficiency. However, our study also has limitations, including the size of the sample and the diversity of cultural backgrounds. Future research should explore the impact of artificial intelligence management on sustainability under different cultural and economic contexts, as well as how to formulate strategies to maximize these positive effects.

Seventhly, 91 participants were found to be working in different industries that they present other SMEs industries. Although they were organizational members of SMEs in China, it was confirmed that the participants were engaged in different industries than the one we had set in the survey. Therefore, this was a limitation in expanding the types of SMEs and presenting more in-depth research results. In future studies, it is required to set more SMEs industries to derive more specific results.

Furthermore, although the results of this study support the positive impact of artificial intelligence management on green innovation, we acknowledge that there may be alternative explanations. For instance, organizational culture could simultaneously influence the implementation of artificial intelligence management and the adoption of green innovation.

The limitations of our sample and measurement methods may not have fully captured the impact of this culture. Future research should explore how organizational culture could act as a potential mediating or moderating variable, affecting the relationship between artificial intelligence management and green innovation.

Finally, it is necessary to explore the antecedents of sustainable outcomes from various perspectives. In social aspects, sustainable outcomes are influenced by health, value creation, safety, and satisfaction [92]. In previous studies, it was important to improve innovative behavior to increase organizational sustainability and survival, and a moderated mediation model for this was presented while securing the significance of the model [93]. In future studies, it will be necessary to explore the mediating factors in the process of members' innovative behavior increasing sustainability. In addition, research should be conducted to explore a moderated mediation model that can increase sustainability. In relation to organizational systems, a high-performance work system facilitates and increases organizational innovation performance [94]. Therefore, it is worth verifying the mediating effect of innovation performance on the impact of high-performance work systems on organizational sustainability outcomes.

6. Conclusions

In summary, this study emphasizes the crucial roles of artificial intelligence management and innovation culture in stimulating knowledge sharing and green innovation among employees in Chinese SMEs. The results indicate that artificial intelligence management has a positive (+) influence on both knowledge sharing and green innovation, with knowledge sharing partially mediating this relationship. Furthermore, innovation culture moderates the relationship between artificial intelligence management/knowledge sharing and green innovation, as well as the mediating role of knowledge sharing in the model.

These findings provide important insights into how Chinese SMEs can stimulate employees' green innovation through artificial intelligence management, knowledge sharing among employees, and innovation culture. It also highlights the importance of artificial intelligence management in influencing employee green innovation.

By emphasizing the positive impact of artificial intelligence management, the moderating role of innovation culture, and the mediating role of knowledge sharing, this study further enriches the existing literature on relevant variables and employees in Chinese SMEs. Practical implications suggest that SMEs should increase the adoption of artificial intelligence management in the workplace to stimulate knowledge sharing among employees and cultivate the formation of an innovation culture, ultimately enhancing employees' level of green innovation during work processes.

Finally, this study underscores the pivotal role of artificial intelligence management in promoting employees' green innovation within SMEs. This aligns with the United Nations' Sustainable Development Goals, particularly SDG 9, which focuses on industry, innovation, and infrastructure, and SDG 12, which emphasizes responsible consumption and production. By effectively leveraging artificial intelligence, organizations can enhance knowledge sharing—a critical mediator in green innovation essential for sustainable practices. This enhancement, in turn, contributes to SDG 4 on Quality Education by fostering a more knowledgeable workforce. Furthermore, cultivating an innovative culture that supports SDG 8 for decent work and economic growth can amplify the impact of artificial intelligence management and knowledge sharing on green innovation. Such a culture emphasizes the importance of collaborative work environments and creative thinking, which are integral to achieving SDG 17, partnerships for the goals, by promoting collaborative efforts toward sustainable outcomes. These findings suggest that SMEs can make substantial contributions to global sustainability efforts by integrating artificial intelligence management to stimulate knowledge sharing and nurture an innovative culture, thereby advancing progress toward the SDGs through more sustainable and responsible business operations.

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