

Article

Leveraging Digital Empowerment for Green Product Innovation: Unraveling the Mediating Role of Resource Integration and Reconfiguration in Chinese Manufacturing Enterprises

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Abstract: The rapid digital transformation and the imperative for sustainable practices have made it crucial for Chinese manufacturing enterprises to adapt and achieve green product innovation by effectively utilizing digital technologies. This study takes a resource-based perspective from strategic management and develops a chain mediation model to examine how Chinese manufacturing enterprises can achieve green product innovation through digital empowerment. A questionnaire survey was conducted with 229 managers, and a multiple mediation model was employed to test the hypotheses. The findings highlight that a higher level of digital business intensity positively influences green product innovation, with resource integration playing a significant mediating role. However, the mediating effect of resource reconfiguration is found to be non-significant. Furthermore, there exists a sequential chain mediation effect of resource integration and resource reconfiguration in the relationship between digital business intensity and green product innovation. To ensure successful green product innovation, Chinese manufacturing enterprises need to focus on accumulating R&D experience and knowledge through resource integration, enabling them to identify latent market demand and develop corresponding green products. This approach facilitates an organic fusion of incremental and breakthrough innovation. The study contributes to the advancement of management paradigms driven by digitalization and the theory of green product innovation, offering valuable insights for Chinese manufacturing enterprises seeking to achieve green innovation through the effective utilization of digital technologies. Additionally, it provides practical implications for enhancing the adaptability of Chinese manufacturing enterprises to market demand and promoting the adoption of “dual carbon” practices.

Keywords: digitalization; digital business intensity; green product innovation; resource integration; resource reconfiguration



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1. Introduction

China's economy is currently in a critical phase of transitioning from high-speed growth to high-quality development. As a pillar of the national economy, the manufacturing industry is an important component of achieving high-quality economic development [1]. China is the world's largest manufacturer, but it is also the country with highest carbon dioxide emissions globally [2]. Based on this situation, the Chinese government has proposed striving to achieve the goal of peaking carbon emissions before 2030 and achieving carbon neutrality before 2060 [3]. The setting of the “dual carbon” targets is

driving the industrial enterprises, particularly those with high pollution intensity, to accelerate the research, development, and promotion of green innovative products. Green product innovation can reduce waste emissions, promote efficient resource utilization, and contribute to cost reduction and enhanced reputation for businesses [4]. The green product innovation of manufacturing enterprises requires minimizing the energy consumption of new products throughout the entire life cycle of production, distribution, use, and disposal, and maximizing the reduction of negative impacts on human health and the natural environment [5]. More and more enterprises are gradually realizing the significance of green product innovation, strengthening their environmental consciousness, and refraining from producing products that contain toxic and harmful substances [6]. However, how to promote the “harmonious coexistence” of green product transformation in the manufacturing industry and economic development while adhering to the strategy of sustainable development remains a challenging issue that both the theoretical and practical realms urgently need to explore. Due to limited resources and mismatched capabilities, the majority of manufacturing enterprises in China often find themselves at a relative disadvantage in new green product development.

The emergence of digital technology has provided new opportunities for green product innovation in manufacturing enterprises and serves as a crucial catalyst for China’s achievement of the “dual carbon” goals [7]. In the context of the digital economy era, rapidly advancing digital technologies and digitalization have gradually penetrated all aspects of enterprise production and operations [8]. This digital transformation brings about a digital empowerment effect, which not only provides technological support for enterprise production and operations but also contributes practical solutions to green product innovation within the enterprise [9]. Business digitalization acts as the driving force behind digital empowerment, providing the technological infrastructure and resources necessary to empower organizations and individuals. Business digitalization represents the adoption and integration of digital technologies within an organization’s operations and processes, leveraging emerging digital technologies such as big data, cloud computing, artificial intelligence, and others to enhance productivity, intellectual capital, and innovation capabilities [10–12]. The digital empowerment effect, encompassing dimensions such as structural empowerment, psychological empowerment, and resource empowerment [13], is the result of business digitalization. It enables organizations to leverage digital technologies and resources, improving the efficiency of resource exchange, combination, and integration [14]. In the Chinese context, digital technology plays a critical role as a source of green value creation, contributing to green product innovation within manufacturing enterprises [15].

However, the widespread use of digital technology and its application in the process of digital transformation have also raised a dilemma regarding green transformation plans based on digital technology in China. On the one hand, organizations aim to utilize digital strategies to optimize existing organizational capabilities and achieve digital transformation. On the other hand, they have concerns about potential disruptions to existing processes and structures during the digital transformation process [16]. Therefore, navigating the contradiction between opportunities and challenges and effectively utilizing digital transformation to improve the performance of new product development becomes a topic of concern for businesses in China.

Currently, research on the intersection of digitization and green product innovation is fragmented, with only a limited number of scholars investigating the impact of digitalization on green product innovation in enterprises [17]. However, these studies primarily provide a general exploration of the relationship between digitization and greening, without delving into the specific mechanisms through which digital empowerment influences the green product innovation of manufacturing enterprises. As an important microeconomic subject in the context of the rapid development of the digital economy, how to effectively use digital technology to achieve green product innovation is of great significance for manufacturing enterprises to achieve sustainable competitive advantages and promote high-quality economic development.

This study adopts the perspective of digital empowerment to explore the pathways for promoting green product innovation in traditional manufacturing enterprises in China during the process of digital transformation. By examining the relationships between business digitalization, digital empowerment, and green product innovation, we aim to shed light on how these variables interact and contribute to the achievement of sustainable development goals in the manufacturing sector.

In response to the aforementioned practical and theoretical bottlenecks, this study focuses on Chinese traditional manufacturing enterprises and conducts a questionnaire survey. It constructs a chain-mediated effect model to deconstruct the process by which manufacturing enterprises, through digital transformation from the perspective of digital empowerment, integrate and reconstruct their existing organizational resources. This process leads to the formation of dual capabilities in resource integration and reconfiguration, ultimately facilitating green product innovation. Theoretical contributions of this study encompass:

- Advancing the understanding of the role of digital empowerment in the context of green product innovation in manufacturing enterprises. By examining the process of digital transformation and resource integration and reconstruction, this study sheds light on how digital empowerment facilitates and influences green product innovation.
- Introducing the concept of dual capabilities in resource integration and reconstruction. This study highlights the importance of not only integrating existing organizational resources but also reconstructing them in the digital transformation process. It contributes to the literature on resource orchestration and provides insights into the development of key organizational capabilities for green product innovation.
- Offering empirical evidence from Chinese traditional manufacturing enterprises. By focusing on this specific context, the study provides valuable insights into the digital transformation challenges and opportunities faced by traditional manufacturing enterprises in China. The findings can inform management practices and policy-making in promoting green product innovation in the manufacturing sector.

Overall, this study contributes to the understanding of the mechanisms through which digital empowerment drives green product innovation in manufacturing enterprises, providing theoretical insights and practical implications for both academia and industry.

In the following sections, we delve into the theoretical foundations and conceptual framework of our study. Section 2 provides an overview of the relevant literature on digital business intensity, resource integration, and green product innovation. Section 3 details the research methodology, including the measurement scales, sample selection, and data collection procedures. In Section 4, we present and analyze the empirical findings, focusing on the relationships between digital business intensity, resource integration and reconfiguration, and green product innovation. Section 5 discusses the theoretical implications, practical implications, limitations, and avenues for future research. Finally, Section 6 offers a summary of our key findings and conclusions. By structuring the paper in this way, we aim to provide a comprehensive understanding of the study and its contributions.

2. Theoretical Foundation and Research Hypotheses

2.1. Green Product Innovation

Green product innovation refers to the practice of introducing green concepts in the stages of product design, production, and marketing, with the aim of minimizing the energy consumption of new products throughout their entire life cycle (including production, distribution, use, and disposal stages) and maximizing the reduction of negative impacts on human health and the natural environment [18]. Green product innovation can not only meet the requirements of ecological and environmental protection, but also create new market opportunities for companies, helping them maintain a competitive advantage [19]. Green product innovation is different from traditional product development, which focuses on integrating manpower, tools, and technology to introduce new products quickly, capture market opportunities, and promote economic benefits [20]. Green product

development requires the integration of manpower, tools, technology, and the environment while considering the product's impact on the environment, which is more complex. Green products must achieve economic benefits while minimizing their negative impact on the environment [21].

Currently, research on green product innovation mainly focuses on two aspects: First, studying the promoting or inhibiting effects of environmental regulations, policy, market factors, and technology on regional, industrial, and enterprise-level green products [22]. This includes research on green subsidies, green credit policies, low-carbon pilot cities, consumer environmental demands, and the promotion and application of environmental protection technologies [23]. The second aspect of research on enterprise green product transformation focuses on the models and value-added paths. Green hydrogen/green electricity substitution, raw material/product structural adjustment, process reengineering, digitalization, and intelligentization are considered as the mainstream low-carbon strategies for high-carbon emission industries [24]. The green product innovation models include [25]:

- Environmental material innovation model: Using new environmentally friendly materials such as biodegradable materials, recyclable materials, and degradable materials to achieve product greenification.
- Environmental process innovation model: Using new environmentally friendly processes such as clean production technologies, circular economy technologies, and energy-saving technologies to achieve product greenification.
- Green design innovation model: Using ecological design, environmental evaluation, and other technical means in the product design phase to achieve product greenification.
- Green marketing innovation model: Using new marketing methods such as green brand building and green marketing communication to achieve product greenification.
- Green digitization model: Using digital technologies such as the Internet of Things, big data, and artificial intelligence to achieve product intelligence and greenification.

In summary, the goal of green product innovation models is to achieve product greenification and sustainable development through technology and innovation, thereby promoting corporate sustainable development and environmental protection [26]. Enterprises can choose suitable green product innovation models based on their own situation and market demand, and strengthen cooperation with stakeholders to jointly promote green product innovation.

2.2. Business Digitalization and Green Product Innovation from The Perspective of Digital Empowerment

The original meaning of the term “empowerment” refers to authorizing and granting additional authority to employees within an enterprise [27]. With the rise of digital technology and industrial Internet, digital empowerment has gradually become a hot topic. Digital empowerment refers to the use of digital technology to transform organizational structures, business processes, and management systems, and to enhance the skills, knowledge, and confidence of employees [28]. Digital empowerment is also the process in which enterprises are driven by the application of digital technology to promote their innovation and growth [29]. It not only emphasizes the application of digital technology in enterprise innovation and operations but also focuses on enhancing the capabilities of the empowered objects [30]. Currently, digital empowerment mainly includes the following three dimensions: structural empowerment, psychological empowerment, and resource empowerment [31].

Structural empowerment focuses on improving objective external conditions (such as organizational, institutional, social, and cultural conditions) to empower organizations to take action [32]. In the context of digitalization, structural empowerment emphasizes the use of digital technology to eliminate structural barriers that prevent enterprises from accessing information, opportunities, resources, and other structural obstacles [14]. This type of digital empowerment will change situational conditions, improve organizational efficiency, and focus on using digital technology (such as DingTalk) to enhance organizational structure, policies, and channels, increase flexibility and response speed [33].

Psychological empowerment focuses on improving social psychology and intrinsic motivation, or personal subjective interpretation (such as confidence, self-awareness, and self-confidence), so that employees feel that their fate is in their own hands [34]. Digital technology can facilitate direct communication and free access to information among employees, as well as cross-functional and cross-departmental decision-making [35], helping employees improve their skills and management abilities, and thereby enhancing their self-efficacy and unleashing their work potential [12].

Resource empowerment can be described as the ability to improve the ability of those who lack resources to obtain, control, and manage them. As a means of connecting resources, digital technology is reflected in various methods of resource acquisition, such as virtual teams, crowdfunding, and other business models enabled by digital technology, which facilitate resource collaboration and innovation among multiple organizations [36]. Through this type of digital empowerment, organizations can leverage specific capabilities to integrate the factors that stably improve digital transformation with the factors that create breakthroughs [37]. Small and medium-sized manufacturing enterprises are likely to achieve breakthroughs even with limited resources.

Digital empowerment provides a new perspective for studying enterprise green product innovation [38], and traditional manufacturing enterprises can use digital empowerment to solve the dilemma encountered in the process of green product transformation, and effectively cope with uncertainty (such as highly turbulent environments or disruptive innovation behaviors) [39].

Digital empowerment and business digitalization are closely intertwined and mutually reinforcing [40]. Business digitalization (BD) represents the process and strategy of adopting and integrating digital technologies within an organization's operations and processes [10]. BD provides the necessary technological infrastructure and resources for digital empowerment to occur [11]. In this sense, business digitalization serves as the driving force behind digital empowerment, creating an environment where organizations can effectively harness digital technologies to transform their operations and achieve sustainable innovation [41]. The successful implementation of business digitalization paves the way for digital empowerment, empowering individuals and organizations to leverage digital technologies for green product innovation and overall business success [42].

Through digitalization, enterprises can integrate digital technologies into various aspects of their operations and involve customers in emerging digital innovations [43]. In the practice of green product innovation, digitalization will promote the exchange of new ideas between manufacturing enterprises and their value chain partners, further improving or creating green products. Digitalization structural empowerment is conducive to more accurately understanding the personalized needs of consumers and innovating enterprise product and process design solutions, thereby achieving flexible manufacturing and customized production, and providing customers with higher quality and more personalized products or services [44]. For example, Tesla has implemented digital technologies, such as artificial intelligence, to optimize the energy efficiency of their electric vehicles, reducing their environmental impact. They also use digital technologies to monitor and optimize the performance of their solar and energy storage systems.

With the widespread use of information technologies such as artificial intelligence, cloud computing, and machine learning, psychological empowerment is not limited to employees having greater management autonomy, but also includes freeing employees from simple mental activities [45], which helps to produce high-knowledge-added-value products and services, and accumulate rich knowledge resources for green product innovation in enterprises [46]. At the same time, psychological empowerment promotes communication, exchange, and learning among employees, enhances their subjective willingness to share knowledge, and helps improve their digital literacy [47], allowing them to accurately judge and grasp relevant information in the process of green innovation, thereby enhancing their ability to innovate green products.

Digital technology resource empowerment has increased the speed of information transmission and enhanced employees' perception and sensitivity to search for green information and innovation. By divesting underutilized resources within the enterprise, this can improve operational efficiency and reduce the cost of green product innovation [48]. Furthermore, digital resource empowerment enables enterprises to obtain more customer information, understand customer preferences, and explore potential customer needs, which can help them acquire more external resources. By innovating green products based on customer needs, this model reduces the cost and inventory of green transformation, aligns with the enterprise's green development philosophy, and facilitates enterprise green product innovation.

Based on the key role of business digitalization in enhancing green product innovation, it can be concluded that the three dimensions of digital empowerment—structural, psychological, and resource empowerment—are all beneficial to enterprise green product innovation. Chinese traditional manufacturing enterprises, empowered by digital technology in three dimensions, are profoundly influenced by their unique context and characteristics, driving innovation in green products. Structurally, these enterprises face complex supply chains and production processes. Digital technology enables the establishment of efficient and sustainable supply chain networks. Real-time monitoring and data support provided by digital supply chain management systems optimize environmental sustainability and green performance. Collaboration and information sharing among different departments enhance production efficiency and resource utilization, promoting green product innovation. Psychologically, there are differences in employee skills and culture. Digital empowerment offers training and education to enhance digital literacy and skills. Digital tools and platforms familiarize employees with the digital environment, boosting their ability and enthusiasm for participating in green product innovation. It also transforms company culture, fostering innovative thinking and green awareness among employees, driving the advancement of green product innovation. Regarding resource empowerment, these enterprises face challenges of low resource utilization efficiency and increasing environmental pressures. Digital empowerment optimizes resource utilization through fine monitoring and management of energy, water resources, and more. It also facilitates the acquisition and utilization of external resources, such as through digital marketing and customer relationship management systems, driving the development and innovation of green products.

In conclusion, in the realm of Chinese traditional manufacturing enterprises, digital empowerment in the dimensions of structure, psychology, and resources significantly impacts supply chain optimization, employee capability enhancement, and resource utilization efficiency, driving the development of green product innovation. Embracing digital empowerment allows these enterprises to better adapt to environmental changes, enhance competitiveness, and contribute to sustainable development and green transformation. Therefore, this article proposes the following hypothesis:

Hypothesis 1 (H1). *Business digitalization is beneficial in promoting manufacturing enterprise green product innovation.*

2.3. The Mediation Effect of Resource Integration and Reconfiguration

2.3.1. Theoretical Foundation

From the perspective of sustainable competitive advantage believe that understanding the internal mechanisms is the fundamental issue of maintaining competitive advantage under market equilibrium forces, which has gradually evolved into important theories such as resource-based view (RBV) [49] and dynamic resource management theory [50].

RBV was first proposed by Wernerfelt [51] and later conceptualized by Barney [52]. RBV believes that resources are tangible or intangible assets, abilities, processes, knowledge, information, and other production factors that a company owns or controls and can be used to produce and improve operational efficiency [53]. Different companies have different resources,

and resources cannot easily flow between companies. Competitors cannot imitate or substitute them in the short term, thus creating a specific resource advantage that forms an isolation mechanism and a competitive advantage for the company [54]. Only resources that meet the VRIN criteria (valuable, rare, inimitable, nonsubstitutable) can create value that exceeds competitors for the company [55].

Effective resource management is crucial for creating value because the way resources are utilized is just as significant, if not more, than the mere ownership or possession of those resources. In other words, it's not enough to simply have access to resources; it's how those resources are allocated, utilized, and optimized that ultimately determines their true value. Resource orchestration involves making informed decisions about how best to allocate resources to achieve organizational goals, minimize waste, and maximize efficiency [56]. By doing so, businesses can unlock the full potential of their resources and create value for themselves and their stakeholders. Resource management is a micro foundation for achieving key capabilities and resource bundling, and can effectively explain how managers integrate, bundle, and leverage resources to form key capabilities for gaining competitive advantage for the enterprise. Resource management includes three basic processes [50]: firstly, resource construction (i.e., resource structuring), which refers to the acquisition, accumulation of valuable resources, and the disposal of useless resources to build a resource pool that is necessary for the development of the enterprise; secondly, resource bundling (i.e., resource capability), which refers to the early stage of learning and integrating resources to enhance the company's capabilities; thirdly, resource leverage (i.e., resource leveraging), which refers to the process of releasing valuable resources through the combination of resources and capabilities to achieve value transmission. In each resource management process, resources are a necessary condition for sustainable competitive advantage, and the capabilities matching the development stage based on scattered resources are intermediate products.

Resource management theory serves as a fundamental framework for understanding the effective utilization of resources in creating value and gaining a competitive advantage [57]. It emphasizes the significance of resource allocation and orchestration within an organization, highlighting that the way resources are managed and integrated is crucial for maximizing their potential and achieving organizational goals. By delving deeper into the concepts and principles of resource management theory, the research framework can provide a more comprehensive understanding of the mediating variables. In the context of this study, resource management theory can be applied to explain how resource integration and resource reconfiguration act as mediating variables between digitization and green product innovation. Resource integration involves optimizing resource allocation and utilization within the organization, facilitating collaboration and knowledge sharing among stakeholders involved in the green product innovation process. This aligns with the resource management processes of resource construction (acquisition and accumulation of valuable resources) and resource bundling (integration of resources to enhance capabilities).

Furthermore, resource reconfiguration, which entails reallocating and recombining existing resources to support new strategic initiatives, may have a limited impact in the specific context of green product innovation in Chinese manufacturing firms. It is important to examine and discuss the challenges and potential barriers associated with resource reconfiguration, particularly within the realm of green innovation. By addressing these challenges, organizations can effectively leverage their resources and capabilities to drive green product innovation.

In the digital economy, production resources have expanded beyond traditional factors like labor, land, and capital [58]. Digital technology has emerged as a new resource that is gradually integrated into the entire process of enterprise production and operation, significantly impacting green innovation [59]. The process of digitalization is accompanied by iterative upgrades in organizational capabilities [60]. As a novel economic resource for value creation, digital technology resources improve resource deployment by accurately integrating and reconfiguring resources.

By applying resource management theory to the context of digitalization and green product innovation, we can gain a deeper understanding of how organizations integrate and reconfigure their resources to drive sustainable innovation. Resource management theory helps explain how firms effectively deploy digital technology resources to enhance their capabilities for green product innovation. Digital technology resources not only serve as tools for process optimization and efficiency improvement but also enable companies to access and analyze large amounts of data, leading to better decision-making and the development of eco-friendly products. Integrating digital technology resources into the overall resource pool enhances firms' ability to innovate, collaborate, and respond to environmental challenges.

Furthermore, resource management theory highlights the importance of resource integration and reconfiguration. Resource integration involves optimizing the allocation and utilization of resources, both traditional and digital, to enhance collaboration and knowledge sharing within the organization. Digitalization facilitates seamless information flow and collaboration, enabling firms to effectively integrate resources across different departments and stakeholders. Resource reconfiguration, on the other hand, involves the reallocation and recombination of resources to support new strategic initiatives. In the context of digitalization and green product innovation, firms may need to reconfigure their resources to align with sustainability goals and leverage digital technology in their product development processes.

By deepening the integration of resource management theory into the research framework, the study can provide a more comprehensive analysis of the mediating variables, enhancing the understanding of the relationship between digitization and green product innovation in Chinese manufacturing firms.

In conclusion, the integration of digital technology resources into the resource pool of organizations has significant implications for green product innovation. Leveraging resource management theory as the theoretical foundation allows us to better comprehend the mediating variables of resource integration and reconfiguration in the context of digitalization and their impact on green product innovation.

2.3.2. Resource Integration

In accordance with the resource-based view (RBV), the process of resource integration involves efficiently identifying, procuring, and distributing external resources [61]. This refers to the notion that businesses must not only possess resources, but also effectively integrate them into their operations in order to create competitive advantages and achieve organizational objectives [62]. By leveraging external resources in a strategic and effective manner, businesses can enhance their capabilities and achieve sustainable growth in their respective markets.

Digitalization enables enterprises to integrate internal and external resources, by utilizing digital technologies to improve their organizational efficiency and explore new innovation opportunities. This can enhance their green innovation research and development capabilities, enabling enterprises to produce more green products through green design and ultimately achieve their fundamental green goals. Digital technology provides enterprises with the conditions to acquire resources, allowing organizations to process, improve and take action on digital resources [63]. The rise of digital information technology has increased the level of information digitization, enabling information to be decoupled from devices and facilitating real-time transmission, storage, and conversion [64]. This digital decoupling enhances an organization's ability to perceive the external environment, enabling timely access to rich information and the ability to make corresponding adjustments based on the acquired information, thus improving the organization's agility in responding to the external environment [65]. Therefore, enterprises possessing high-level digital business intensity can leverage digital technologies to obtain technical information and knowledge related to their business processes. This improves their information acquisition capabilities, thereby facilitating their ability to respond to environmental changes, identify market op-

opportunities, and develop strategies for green product development. Moreover, enterprises can utilize digital technologies to identify high-quality resources and redundant resources, and promptly transfer the redundant resources to other departments or organizations that need them. Additionally, enterprises can collaborate with other departments to engage in green product innovation activities targeting these redundant resources, thereby fully utilizing them and reducing resource depreciation losses and inventory costs. Furthermore, the digitalization of internal business processes within an enterprise promotes the quick flow and sharing of information resources across various business departments, facilitating the integration of existing research and development-related resources. This enables employees to effectively utilize relevant organizational resources to conduct research and development activities, thereby improving the efficiency and effectiveness of green product development (e.g., shortening the R&D cycle and achieving higher profits/investment returns).

Furthermore, it is essential to consider the specific context of China in understanding the mediating role of resource integration between business digitalization and green product innovation. China's unique business environment, characterized by its large-scale manufacturing sector, evolving digital landscape, and increasing emphasis on sustainability, shapes the dynamics of resource integration and its impact on sustainable innovation outcomes [35]. In the Chinese context, organizations face distinct challenges and opportunities in integrating resources effectively to drive green product innovation. The rapid pace of technological advancements and digital transformation in China's manufacturing industry necessitates a comprehensive understanding of how resource integration mediates the relationship between business digitalization and green product innovation. Several studies have explored the role of resource integration in facilitating innovation in Chinese manufacturing enterprises [66,67]. However, there remains a need to specifically examine the mediating effect of resource integration in the context of business digitalization and its impact on sustainable innovation outcomes within the Chinese manufacturing context.

Building on the existing literature and the unique characteristics of the Chinese context, the following mediation hypotheses are proposed:

Hypothesis 2 (H2). *Resource integration plays a mediating role in the relationship between business digitalization and green product innovation.*

2.3.3. Resource Reconfiguration

Resource reconfiguration refers to the appropriate transformation undertaken by enterprises, involving continuous or periodic asset rearrangement, business model redesign, and organizational structure adjustments [68]. It fundamentally changes organizational design principles, such as altering functional and departmental organizational principles, breaking through rigid corporate situations, and achieving new benefits. The ability of enterprises to reconfigure resources means that they can recombine and restructure resources, thereby achieving business model innovation [69]. This is because resources form the basis of business models, and elements such as value proposition, value creation, value delivery, and value capture are all dependent on resources.

High-level digital business intensity helps enterprises overcome path dependence and achieve more flexible market responsiveness and green product innovation through dynamic resource reconfiguration [70]. The rapid development of digitization has intensified the complexity and variability of the competitive environment, blurred the boundaries of enterprises, weakened their path dependence, and made it more favorable for them to engage in green product innovation activities through resource reconfiguration. Digital-enabled manufacturing enterprises can introduce new resources and capabilities through dynamic resource reconfiguration, achieving diversified product and service innovation to break path dependence and respond to market changes and demand [71]. For example, by introducing new R&D teams or partners, a diversification of technology and talent can be achieved, thereby promoting green product innovation. Meanwhile, the high-level digital business intensity of enterprises helps to increase the frequency of communication

among various business links within the organization, improve the sharing of knowledge both internally and externally, and improve organizational learning and adaptation capabilities [72]. The application of digital technology can lower the cost of communication between members, improve the efficiency of communication and information exchange, increase the heterogeneity of resources and knowledge, and promote collaborative innovation among different members [73]. This increases the possibility of launching green product innovations by strengthening internal knowledge management, improving employee skills and knowledge and responding to market demand and challenges.

In summary, digitalization of manufacturing enterprises can overcome path dependence, break old thinking and patterns, and achieve more flexible market responsiveness and green product innovation through dynamic resource reconfiguration.

Understanding the role of resource reconfiguration in the Chinese context is essential for comprehending the mechanisms through which business digitalization contributes to green product innovation outcomes. China's manufacturing landscape, characterized by its dynamic market conditions, evolving regulatory environment, and increasing emphasis on environmental sustainability, presents unique challenges and opportunities for resource reconfiguration in driving sustainable innovation [2]. Several studies have examined the role of resource reconfiguration in facilitating innovation in Chinese manufacturing enterprises [38,67]. However, there is a need to specifically investigate the mediating effect of resource reconfiguration in the context of business digitalization and its impact on green product innovation outcomes within the Chinese manufacturing context.

Taking into account the existing literature and the specific characteristics of the Chinese context, we propose:

Hypothesis 3 (H3). *Resource reconfiguration plays a mediating role in the relationship between business digitalization and green product innovation.*

Efficient resource integration provides support for the successful implementation of the green product innovation paradigm. However, the success of green product innovation paradigm may lead to established routines and institutional controls that can result in organizational rigidity. In the current turbulent market environment with increasingly diverse and personalized customer demands, enterprises need to go beyond resource integration and engage in resource reconfiguration [74]. The main reason for resource management in enterprises lies in the fact that innovation in each green product or service involves the integration and reconfiguration of existing resources. The ability to integrate and acquire resources helps to discover and create opportunities, but to execute a green product innovation strategy, enterprises need to reconfigure their resources and capabilities. With the implementation of digitalization, the enterprise's data analysis capabilities may be relatively improved compared to before, and the data analysis capabilities will bring incremental process innovation, further improving the reconfiguring ability and achieving business model adjustment [75]. The ability to reconfigure resources helps to promote organizational evolution and improve adaptability, enabling enterprises to survive and develop in the digital era, and over time, improve their green innovation capabilities. Therefore, digitalization may continuously revise and optimize the enterprise's ability to integrate resources by strengthening organizational reconfiguring capabilities, making the enterprise's green product innovation model more compatible with environmental factors. Based on the analysis above, the following hypothesis is proposed:

Hypothesis 4 (H4). *Resource integration and resource reconfiguration play a sequential mediating role in the relationship between business digitalization and green product innovation.*

Based on the hypothesized analysis, this study constructs a multiple mediation model of resource integration and resource reconfiguration in the relationship between digital empowerment and green product innovation, as shown in Figure 1.

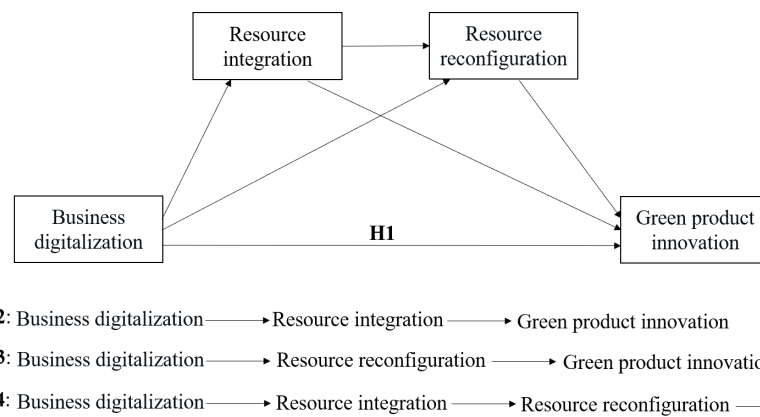


Figure 1. Research model.

3. Research Design

3.1. Data Collection

The main source of data for this study was Chinese manufacturing enterprises that underwent green product transformation using digital technologies such as hardware technology, software technology, blockchain technology, big data technology, cloud computing technology, artificial intelligence technology, internet of things technology, virtual reality technology, and more. To ensure that the organizations in our sample had implemented digital technologies for their transformation, we employed a multi-step approach. Firstly, we conducted thorough background research on each organization to gather information regarding their digitalization initiatives. We extensively reviewed company websites, annual reports, and relevant industry publications to identify organizations that explicitly mentioned their adoption of digital technologies or efforts towards digital transformation. Additionally, we utilized industry databases and reports to identify manufacturing organizations known for their digitalization initiatives and innovation in the field. These sources provided valuable insights into the digital transformation strategies and technologies employed by various companies. Furthermore, during the data collection phase, we included specific questions in our questionnaire survey to directly assess the presence and extent of digital technologies implemented by the participating organizations. These questions aimed to capture information about the types of technologies adopted, their integration within the organizational processes, and the overall level of digitalization achieved. By combining these research methods and survey inquiries, we ensured that our sample consisted of manufacturing organizations that had indeed implemented digital technologies for their transformation. This comprehensive approach enabled us to gather data from organizations actively leveraging digitalization to enhance their operations and drive innovation in green product development. Overall, these steps were taken to rigorously select manufacturing enterprises that had undergone digital transformations, ensuring the relevance and accuracy of our study's findings.

The questionnaire distribution in this study primarily utilized on-site and online methods. The data collection process took place over a period of six months, from March 2022 to September 2022. To ensure the quality of questionnaire collection, several measures were implemented. Firstly, prior to the formal survey, the research personnel received training on the questionnaire survey process, guidelines, and relevant considerations. Secondly, before each survey, we contacted the respondents in advance through phone calls, WeChat, or other means to introduce the purpose and method of the survey, confirm their willingness to participate, and determine the survey location and time. Additionally, during the surveys, the questionnaire filling process and guidelines were explained in detail, and any questions raised by the respondents during the filling process were addressed. Finally, if respondents were unable to complete the questionnaire promptly, the research team would send them an electronic version of the questionnaire or request them to return it via mail within a specified timeframe. It was ensured that at least two questionnaires were

distributed to each surveyed enterprise. A total of 423 questionnaires were distributed in this survey, and 326 questionnaires were collected, resulting in a questionnaire response rate of 75.46%. After excluding questionnaires from enterprises with strong regularity and incomplete or clearly erroneous responses, a final sample size of 229 valid responses was obtained, resulting in an effective questionnaire response rate of 54.14%.

In this study, the t-test method was employed to compare the differences between the participating enterprises and those that did not respond to the questionnaire survey in terms of attributes such as company type, company development stage, and personnel scale. The results of t-tests with a significance level of $p < 0.05$ indicating that there were no significant differences among the various channel pairs, suggesting that data from different channels can be effectively combined for analysis. The sample statistics are presented in Table 1.

Table 1. Descriptive statistics.

Items	Category	Frequency	Percentage
Property	State-owned enterprise	74	32.3
	Private enterprise	113	49.3
	Foreign-owned enterprise	16	7.0
	Others	26	11.4
Stage of development	Start-up stage	29	12.7
	Growth stage	74	32.3
	Maturity stage	113	49.3
	Saturation stage	13	5.7
Personnel scale	Below 100	58	25.3
	100–500	59	25.8
	501–2000	44	19.2
	Above 2000	68	29.7

$N = 229$.

To examine the presence of common method bias, this study employed confirmatory factor analysis. Initially, a confirmatory factor analysis model, M1, was constructed. Subsequently, a model, M2, incorporating a method factor was developed. A comparison of the key fit indices between M1 and M2 yielded the following results: $\Delta RMSEA = 0.009$, $\Delta CFI = 0.029$, $\Delta TLI = 0.008$, $\Delta GFI = 0.024$, $NFI = 0.016$. The changes in these fit indices were less than 0.03, indicating that the model did not show significant improvement after including the common method factor. This result suggests the absence of any substantial concerns regarding common method bias.

3.2. Variable Measurement

In this study, we adopted a rigorous approach to variable measurement, drawing upon established scales from previous scientific research to ensure reliability and validity. However, we also recognized the importance of tailoring the measurement items to the specific context of our study. To achieve this, we conducted field investigations and multiple interviews with managers, which greatly informed the development of our measurement items for the four latent variables. The interviews were conducted with a diverse group of managers from various industries and organizations that aligned with our research focus. These interviews provided an opportunity to explore and understand the complexities and intricacies of the variables under investigation. During the interviews, we followed a semi-structured approach that allowed for a comprehensive exploration of the topics of interest while also providing flexibility for managers to share their unique perspectives. The interview questions were designed to cover a wide range of aspects, including the current digital initiatives, resource integration processes, challenges faced, and strategies employed for green product innovation. The interviews were conducted in a confidential and professional manner, ensuring the anonymity of the participating organizations and in-

dividuals. The insights and information obtained from these interviews were then analyzed and synthesized to inform the development and refinement of our measurement items. By engaging with these organizations and conducting interviews with managers who have hands-on experience, we were able to gather rich and nuanced data that greatly contributed to the content validity and relevance of our measurement items. This collaboration with industry partners not only enhanced the robustness of our study but also allowed us to bridge the gap between academia and industry, ensuring the practical applicability of our research findings. Combining the insights from the interviews with the existing scales, we refined and finalized the measurement items for each latent variable. This process ensured that our scales captured the unique characteristics and context-specific elements of the variables under investigation. By incorporating the perspectives of managers through interviews and field investigations, we enhanced the content validity and relevance of our measurement items, thereby strengthening the overall quality of our study.

3.2.1. Digital Business

Digital business intensity is an important variable that characterizes the digital environment of enterprises, reflecting the degree of application and dependence on digital technology in various aspects of their business processes [76]. We adopted the scale developed by Joseph & Pratik [77], which measures an organization's digital business intensity. It consists of three measurement items: (1) We use digital technologies (e.g., analytics, big data, cloud, social media, mobile) in our business transactions; (2) We use digital technologies (e.g., analytics, big data, cloud, social media, mobile) in our firms operations; (3) We are constantly investing in digital technology-enabled initiatives (e.g., analytics, big data, cloud, social media, mobile) in our internal operations.

3.2.2. Resource Integration and Reconfiguration

Drawing on the research of Wilden & Gudergan [78], this paper uses two different styles of indicators to measure the process of resource integration and resource reconfiguration. Resource integration assesses the extent to which organizations integrate and utilize resources in their actual work. It comprises three measurement items: (1) Enterprises can integrate various resources according to development needs; (2) Enterprises can allocate all kinds of resources reasonably according to the changes in the environment; (3) The waste of resources is not serious when enterprises integrate resources. Resource reconfiguration measures an organization's ability to make timely adjustments to its strategic, operational, and structural aspects. It also includes three measurement items [67]: (1) Enterprises can adjust their strategic objectives in time to meet the needs of the competition; (2) Enterprises can effectively adjust the internal production and operation process to meet competitive demand; (3) Enterprises can adjust their organizational structure in time to meet the needs of the competition.

3.2.3. Green Product Innovation

Green product innovation aims to improve product design by using non-toxic compounds or degradable materials in the production process, thereby minimizing the adverse impact on the environment [79]. This includes improving product durability and recyclability, reducing the use of raw materials, selecting environmentally healthier materials, and removing harmful substances [25]. Therefore, measuring green product innovation needs to cover the entire product lifecycle, including the complete process of research and development, production, sales, use, disposal, and recycling. In this study, the scale developed by Huang and Li [65] based on the full lifecycle of product development is used, which includes four items: (1) using environmentally friendly materials with less or no pollution in the production process; (2) improving product packaging design to achieve degradability of the product's external packaging; (3) recycling and reusing waste products; and (4) using eco-labels for green products.

The survey questionnaire uses the Likert 5-point measurement method, where 1 represents “strongly disagree” and 5 represents “strongly agree”. Additionally, the questionnaire includes an introduction and a section for collecting basic information, such as the nature, size, geographical location, and developmental stage of the surveyed companies.

4. Research Results

4.1. Analysis of Reliability and Validity

According to conventional practice, this study employed internal consistency coefficient (Cronbach’s α), composite reliability (CR), and average variance extracted (AVE) to assess the questionnaire’s reliability. Cronbach’s α coefficient was calculated using SPSS 22.0, while CR and AVE values were computed using AMOS 21.0. The results are presented in Table 2. It can be observed from the table that all latent variables have Cronbach’s α coefficients greater than 0.8, with market perception and service innovation exhibiting coefficients above 0.9. The Cronbach’s α values and CR values for each variable ranged from 0.880 to 0.933, exceeding the threshold of 0.700. This indicates that the scale exhibits high reliability. In accordance with the suggestion of Frondel et al. [80], the Average Variance Extracted (AVE) was employed to assess the scale’s convergent validity. The AVE values for each variable ranged from 0.6688 to 0.822, all surpassing the threshold of 0.500. Moreover, the factor loadings were substantial and statistically significant, providing further evidence of strong convergent validity. The results of reliability and validity analysis are shown in Table 2.

Table 2. Reliability and validity analysis.

Variables	Items	Factor Loading	α	CR	AVE
Resource integration	Z1	0.828	0.883	0.858	0.668
	Z2	0.871			
	Z3	0.749			
Digital business intensity	D1	0.889	0.932	0.933	0.822
	D2	0.908			
	D3	0.923			
Resource reconfiguration	R1	0.808	0.880	0.880	0.709
	R2	0.867			
	R3	0.850			
Green product innovation	G1	0.891	0.930	0.931	0.771
	G2	0.894			
	G3	0.876			
	G4	0.850			

N = 229.

Confirmatory factor analysis was conducted using AMOS 21.0 to assess the discriminant validity of the four variables: digital business intensity, resource integration, resource reconfiguration, and green product innovation. A nested model was constructed by combining these variables into a single factor. The nested models for each factor are defined as follows: the 4-factor model includes digital business intensity, resource integration, resource reconfiguration, and green product innovation; the 3-factor model comprises digital business intensity + resource integration, resource reconfiguration, and green product innovation; the 2-factor model consists of digital business intensity + resource integration + resource reconfiguration, and green product innovation; and the 1-factor model incorporates all the factors: digital business intensity + resource integration + resource reconfiguration + green product innovation.

To assess the fit of our models, we relied on widely accepted threshold values. Specifically, a Goodness-of-Fit Index (GFI) and Comparative Fit Index (CFI) above 0.90 were considered indicative of good fit [81,82]. A Root Mean Square Error of Approximation (RMSEA) below 0.08 was considered indicative of acceptable fit, and below 0.05 as in-

dicative of good fit [83,84]. The results presented in Table 3 demonstrate that the selected variables in this study exhibit a high level of discriminant validity. As the number of factors increases, the model fit indices also improve. Specifically, the four-factor model ($\chi^2 = 136.365$, $df = 59$, $\chi^2/df = 2.311$, $RMSEA = 0.076$, $CFI = 0.971$, $TLI = 0.962$, $GFI = 0.918$, $NFI = 0.950$) outperformed the alternative models. These findings confirm the high discriminant validity of the selected variables in this study.

Table 3. Confirmatory factor analysis.

Models	χ^2	df	CFI	TLI	$RMSEA$	GFI	NFI
Four-factor model	136.365 **	59	0.971	0.962	0.076	0.918	0.950
Three-factor model	281.730 **	62	0.918	0.897	0.125	0.823	0.898
Two-factor model	568.636 **	64	0.811	0.770	0.186	0.647	0.793
One-factor model	594.085 **	65	0.802	0.763	0.189	0.650	0.784

$N = 229$, ** $p < 0.01$.

In addition, this study calculated the variance inflation factor (VIF) for each variable in the questionnaire to avoid severe issues of multicollinearity. The results indicate that the VIF values ranged from 1.8 to 3, well below the critical threshold of 10, suggesting the absence of significant multicollinearity. Based on the above analysis, the measurement scales used in this study exhibit good reliability, convergent validity, and discriminant validity.

4.2. Correlation Analysis

The means, standard deviations, and correlation coefficients of each variable are presented in the following Table 4. It can be observed that resource integration is significantly positively correlated with resource reconfiguration, digital business intensity and green product innovation. Resource reconfiguration is significantly positively correlated with digital business intensity and green product innovation. Digital business intensity is significantly positively correlated with green product innovation ($\beta = 0.680$, $p < 0.001$), providing support for H1. These preliminary findings provide necessary support for establishing a multiple mediation model in subsequent analysis.

Table 4. Descriptive statistics and correlation coefficients.

Variables	Means	Standard Deviation	Resource Integration	Resource Re-configuration	Digital Business Intensity	Green Product Innovation
Resource integration	5.601	1.101	1			
Resource reconfiguration	5.772	0.999	0.556 **	1		
Digital business intensity	5.479	1.333	0.581 **	0.593 **	1	
Green product innovation	5.684	1.417	0.515 **	0.596 **	0.680 **	1

$N = 229$, ** $p < 0.01$.

4.3. Hypothesis Results and Analysis

Following the multiple mediation testing method summarized by Hayes (2009) [84], this study adopted Model 6 and utilized the Process plugin in SPSS to examine the mediating effects of resource integration and resource reconfiguration. To accurately assess the significance of each path, we further conducted a Bootstrap analysis with 5000 resampling iterations based on the sample of 229 cases. The results are presented in Table 5 below.

Table 5. Regression analysis.

Regression Equation		Fit Index		Significance of Regression Coefficient		
Dependent variable	Independent variable	R	R ²	F	β	t
Green product innovation (Y)	Digital business intensity (X)	0.680	0.462	195.084 **	0.680	13.967 ***
Resource integration (M1)	Digital business intensity (X)	0.781	0.609	354.111 ***	0.781	18.818 ***
Resource reconfiguration (M2)	Digital business intensity (X)	0.669	0.448	91.563 ***	0.206	12.663 *
	Resource integration (M1)				0.495	6.263 ***
Green product innovation (Y)	Digital business intensity (X)	0.854	0.714	187.044 ***	0.200	3.446 **
	Resource integration (M1)				0.200	3.235 **
	Resource reconfiguration (M2)				0.547	11.392 ***

N = 229, * p < 0.05, ** p < 0.01, *** p < 0.001.

The mediation analysis, depicted in Table 6, reveals that digital business intensity has a significant total mediating effect of 0.511 (95% CI: [0.360, 0.665]) on manufacturing green product innovation, as the interval does not include 0. This mediating effect comprises three distinct paths. First, the indirect effect 1 demonstrates that resource integration mediates the relationship between digital business intensity and manufacturing green product innovation, with an effect of 0.166 (95% CI: [0.010, 0.326]), indicating a significant mediating effect that supports hypothesis H2. Second, the indirect effect 2 shows that resource reconfiguration mediates this relationship, with an effect of 0.120 (95% CI: [−0.018, 0.245]). However, as the interval includes 0, it indicates an insignificant mediating effect, thereby not supporting hypothesis H3. Third, the indirect effect 3 reveals that both resource integration and resource reconfiguration mediate the relationship, with an effect of 0.225 (95% CI: [0.120, 0.359]), indicating a significant mediating effect and supporting hypothesis H4. The total mediating effect is the sum of these three paths, resulting in a value of 0.511. Furthermore, the total effect, which includes the direct effect and the total mediating effect, has a value of 0.723. The effect size of each mediating path, as a percentage of the total effect, is 22.96%, 16.58%, and 31.09%, respectively, with a total chain-mediated effect size of 70.65%.

Table 6. Multiple mediation path analysis.

	Effect Size	Standard Error	95% Confidence Interval		Proportion of Mediation Effect
			Upper Limit	Lower Limit	
Ind1	0.166	0.079	0.010	0.326	22.96%
Ind2	0.120	0.067	−0.018	0.245	16.58%
Ind3	0.225	0.061	0.120	0.359	31.09%
Total mediation effect	0.511	0.076	0.360	0.665	70.65%
Total effect	0.723	0.052	0.621	0.825	/

N = 229.

5. Discussion

5.1. Research Findings

In this study, we aim to explore the relationship between digitization and green product innovation in Chinese manufacturing firms. Green product innovation is a critical aspect of sustainable development and has gained significant attention in recent years. As the global community places increasing emphasis on environmental protection and sustainable practices, companies are seeking innovative solutions to reduce their environmental impact and meet the growing demand for eco-friendly products. Green product innovation involves the development of new products, services, or processes that have a reduced environmental footprint throughout their lifecycle, from raw material extraction to disposal. Chinese manufacturing enterprises are not only important participants in green innovation but also the main promoters of digital transformation, making them an ideal focus for combining these two research themes. The digital transformation of enterprises is an important means for them to achieve high-quality development. Against the backdrop of carbon peaking and carbon neutrality, it is crucial to understand the role of digitalization in the green product innovation of enterprises.

To investigate this relationship, we have constructed a chain mediation mechanism model that links digitalization to green product innovation, with resource integration and resource reconfiguration as the mediating variables. This model has been tested empirically using data from 229 manufacturing enterprises, leading to the following conclusions:

Our research findings provide valuable insights into the role of digitization in driving green product innovation in Chinese manufacturing firms. We have discovered that the intensity of a firm's digital business has a positive influence on green product innovation. In the digital era, traditional manufacturing companies must leverage technological advancements to gain a competitive edge and address sustainability challenges. By embracing digital transformation strategies and harnessing the power of digital technologies, companies can enhance their capabilities for developing and delivering green products.

Furthermore, our study reveals that resource integration plays a mediating role in the relationship between the intensity of digital business and green product innovation. Resource integration refers to the process of optimizing resource allocation and utilization within an organization. In the context of digitization, resource integration enables firms to effectively leverage internal and external resources, access knowledge from diverse sources, and enhance their ability to develop green products. Digitization facilitates the dissemination and sharing of information, breaking down information barriers and promoting collaboration among different stakeholders involved in the green product innovation process.

Interestingly, we find that the mediating effect of resource reconfiguration between the intensity of digital business and green product innovation is not significant. Resource reconfiguration involves the reallocation and recombination of existing resources to support new strategic initiatives. While resource reconfiguration is considered essential for organizational change and adaptation, our findings suggest that in the specific context of green product innovation in Chinese manufacturing firms, the impact of resource reconfiguration may be limited. This could be due to the challenges associated with radical organizational transformations and the legitimacy barriers faced by firms when attempting to reconfigure resources and capabilities for green product innovation.

Overall, our study highlights the importance of digitization in driving green product innovation in Chinese manufacturing firms. By embracing digital transformation and leveraging technological advancements, companies can enhance their competitiveness, meet sustainability goals, and contribute to the transition towards a greener economy. While resource integration plays a significant role in facilitating the relationship between digitization and green product innovation, further research is needed to explore the potential barriers and challenges associated with resource reconfiguration in the context of green innovation.

In conclusion, our findings emphasize the need for manufacturing firms to strategically integrate digitization into their operations and leverage digital technologies to drive green product innovation. Policymakers, industry practitioners, and researchers can draw valuable insights from our study to develop strategies and initiatives that promote sustainable development and facilitate the transition towards a greener and more digitally enabled economy.

5.2. Theoretical Contributions

The theoretical contribution of this study lies in the proposal of a multi-path model for achieving green product innovation based on the resource-based perspective of digitalization empowerment.

Firstly, this study explores the mechanism by which digital business intensity affects green product innovation at the micro-enterprise level. Previous research on green innovation in enterprises has focused on regional or industrial levels [85], and has paid less attention to the influence of enterprise digitalization characteristics and internal resource management capabilities on green product innovation [86]. This article focuses on traditional manufacturing enterprises and investigates the impact mechanism of their

digital business intensity. It not only extends the enterprise digitalization under the digital background to the research on green innovation, but also effectively connects the two fields of digital empowerment and green innovation.

Secondly, some scholars have called for greater attention to be paid to the ability of enterprises to transform resources in green innovation, which is often the key to forming competitive advantages for enterprises [66]. Having strategic resources that are valuable, scarce, non-imitable, and difficult to substitute is not enough. Based on the theories of digital empowerment and resource management, this study explores the mediating mechanism of resource management in the relationship between digital business intensity and green product innovation, revealing the inherent path through which digitalization acts on enterprise green product innovation through specific organizational capabilities, namely resource integration and reconfiguration. These two different capabilities, in various aspects of the organization's business processes including products, value chains, and business models, can assist companies in implementing green innovation strategies in different ways. Furthermore, resource reconfiguring requires a certain foundation of resource integration. These two aspects are not mutually exclusive but complementary. Resource integration is efficient in the initial stage of business, but it can also lead to path dependence. Therefore, resource reconfiguration is necessary to break the existing framework and support companies in dynamically adapting to the market environment. This cycle of resource integration and reconfiguration ultimately leads to sustainable green product innovation. This enriches research related to green product innovation. This article responds to the call of Mousavi et al. [87] and deeply explains the micro-mechanism of implementing green behavior in the process of green product innovation to build green innovation capabilities.

5.3. Practical Implications

The research findings of this article provide important practical insights for the digitalization and green transformation of manufacturing enterprises. Firstly, enterprises should attach great importance to the positive role of digitalization in promoting their own green product innovation. Facing the rapid development trend of the digital economy, enterprises should seize the opportunity of digital transformation and actively integrate digital development concepts into their daily production and operation activities, using digital technology to support their green product innovation. Specifically, enterprises should embed digital business strategies into their green innovation strategies, and use digital transformation to improve their green product innovation and green resource management levels, enhance their green core competitiveness, and achieve sustainable development goals of harmonious coexistence between enterprises and the natural environment, while improving financial performance and reducing the negative impact on the environment.

Secondly, manufacturing enterprises should grasp the phased characteristics of digitalization driving green product innovation, and scientifically and moderately leverage the key capabilities to promote resource integration and reconfiguration actions to realize green product innovation. Therefore, manufacturing enterprise managers should accurately grasp their own stage of digital business, and based on the key abilities activated by digital characteristics, reasonably allocate resource management methods. Through ways such as "integrating resource elements to promote the efficiency of green product R&D" and "reconfiguring resource boundaries to promote dynamic evolution and adaptation of green products", enterprise can achieve the transition of green product innovation from "light green" to "deep green".

Thirdly, although the mediating effect of resource reconfiguration between digital business intensity and green product innovation was found to be non-significant, there are still valuable insights for managers to consider. The results suggest that managers should prioritize resource integration as a key factor in achieving successful green product innovation. By focusing on accumulating R&D experience and knowledge through resource integration, manufacturing enterprises can effectively identify latent market demand and develop

corresponding green products. Managers should also explore additional approaches to enhance the practical application of these findings in a managerial context. For instance, they can consider the role of organizational culture, leadership, and employee engagement in leveraging digital technologies for green innovation. Additionally, it would be beneficial for managers to explore strategies that foster collaboration and knowledge sharing within the organization, facilitating resource integration and promoting green product innovation. Furthermore, it is important for managers to recognize that the absence of a significant mediating effect does not diminish the importance of resource reconfiguration. While it may not serve as a direct mediator in the relationship between digital business intensity and green product innovation, resource reconfiguration can still play a supportive role by enabling flexibility and adaptability in response to changing market conditions and emerging opportunities.

In summary, this study offers valuable insights for managers in Chinese manufacturing enterprises who aim to achieve green innovation through digital empowerment. By prioritizing resource integration, exploring complementary factors, and cultivating a supportive organizational resource base, managers can effectively leverage digital technologies to drive green product innovation and enhance their competitiveness in the market.

5.4. Limitations and Future Directions

This study contributes valuable theoretical and empirical insights into the relationship and mechanisms linking enterprise digital empowerment and green product innovation. However, it is crucial to acknowledge the limitations imposed by data availability and the scope of this article. Firstly, the utilization of a convenience sample may restrict the generalizability of the findings. Future research should aim to employ larger and more diverse samples to enhance the external validity of the study. Additionally, it is important to recognize that the specific digital business strategies, investment intensity, and effectiveness of green product innovation may vary across industries and regions. Therefore, further investigation is warranted to explore the impact of external environmental factors, such as the level of digital economic development in different industries and regions. Secondly, variations in the level of digital business intensity among enterprises can influence the relationship between digital empowerment and green product innovation. Subsequent research should examine this relationship under different levels of digital business intensity to attain a more comprehensive understanding. Thirdly, the cross-sectional nature of the data collected, employing a scale related to green product innovation, may not fully capture the “time lag effect” and inherent characteristics of green product innovation in traditional manufacturing enterprises in China. To address this limitation, future studies should consider utilizing longitudinal or panel data to investigate the deeper relationship between digital empowerment and green product innovation. Additionally, incorporating research methods such as case studies can provide insights into the contextual factors and situational characteristics of green product innovation within traditional manufacturing enterprises. By addressing these limitations, future research can advance our understanding of the intricate dynamics between digital empowerment and green product innovation in traditional manufacturing contexts while enhancing the practical implications of the findings.

6. Conclusions

With the advent of the digital economy era, the development of digital technology has disrupted the green innovation mode of traditional enterprises and given rise to a series of emerging economic forms, such as digital empowerment. These achievements provide a practical foundation for in-depth discussions on how enterprises can effectively utilize digital technology to achieve green product innovation in the technical support of digitalization. This study started from the internal perspective of organizations and constructed a conceptual model of how manufacturing enterprises can influence green product innovation through resource integration and reconstruction based on the of digital empowerment and resource-based theory. The study hypotheses were tested using survey

data from 229 Chinese enterprises to reveal the mediating mechanism of digital business intensity on green product innovation. This study opened the “black box” from practical digitalization to the formation of green product innovation, further improving green innovation research.

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