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The Effect of Digitalization on Ambidextrous Innovation in Manufacturing Enterprises: A Perspective of Empowering and Enabling

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Abstract: Digital transformation has become an inevitable choice for manufacturing enterprises to sustain innovation in the digital world. This study selected a sample of Chinese provinces and A-share companies listed on the Shanghai and Shenzhen stock markets from 2011 to 2021 to examine the relationship between regional digitalization, enterprise digitalization, and enterprise ambidextrous innovation. We found that (1) regional digitalization can promote exploitative and exploratory innovation of manufacturing enterprises. Digitalization plays an empowering effect in the promotion process. The regional digital talent reserve significantly impacts ambidextrous innovation in manufacturing enterprises more than network infrastructure construction, digital technology development, and digital technology application; (2) Enterprise digitalization can promote exploitative and exploratory innovation of manufacturing enterprises. Digitalization plays an enabling impact in this promotion process; (3) Regional digitalization can promote the level of manufacturing enterprise digitalization. In promoting enterprise ambidextrous innovation, digitalization can realize the transformation from regional digitalization empowering to enterprise digitalization enabling. The regional digital talent reserve significantly impacts manufacturing enterprise digitalization more than network infrastructure construction, digital technology development, and digital technology application; (4) The impact of regional and enterprise digitalization on exploratory innovation in large-scale manufacturing enterprises is more significant, and large-scale enterprises are better able to transform from digitalization empowering to enabling. The conclusions of this study have specific theoretical and practical significance for revealing the relationship between digitalization and enterprise ambidextrous innovation and then promoting regional digitalization development, manufacturing enterprise digital transformation, and innovation development.

Keywords: regional digitalization; enterprise digitalization; ambidextrous innovation; empowering; enabling

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1. Introduction

In recent years, global geopolitical conflicts and international trade frictions are have led to higher raw material costs and more supply chain problems for enterprises. The sustainability of manufacturing enterprises is facing many challenges. Digital technologies such as big data and artificial intelligence offer more options for manufacturing enterprises to cope with the complex external environment. At a high level, digital technologies have dramatically changed social and industrial development [1,2]. At the organizational level, digital technology adoption in enterprises can improve the efficiency of resource use [3,4], enterprise competitiveness [5], enterprise performance [2,6], and enterprise sustainability [7]. Therefore, advanced manufacturing enterprises use digital technologies to reshape production models, improve product design and optimize management [8]. Moreover, digitalization significantly impacts enterprise innovation capabilities and processes [9,10]. Notwithstanding these contributions, what are the compound and differential impacts of

digitalization on the different innovation activities of manufacturing enterprises in a period of intelligent transformation? We lack a comprehensive understanding of this issue and its analysis at multiple levels.

Based on different perspectives, existing studies have analyzed the relationship between digitalization and corporate innovation. On the one hand, digital technology can be deeply integrated with the real economy and continuously optimize the innovation environment. Therefore, digital finance and digital economy gradually become essential driving factors for enterprise technology innovation [11–14] and green innovation [15–17]. On the other hand, through extensive use of digital technology, enterprises can achieve digital transformation, which can provide new momentum for technological innovation [18], process innovation [19,20], green innovation [21–23], organizational innovation [24,25], open innovation [26] and business model innovation [27,28]. There is a consensus in the existing literature that digitalization can promote enterprise innovation. However, the literature usually analyzes from a single perspective at the regional or firm level, and there is little literature exploring the impact of digitalization on enterprise innovation from both the regional and firm levels. In reality, the effect of digitalization on enterprise innovation is not only in a single class but also in a multilevel class. Thus, the multilevel mechanisms of digitalization need to be explored [29].

According to organizational ambidexterity, ambidextrous innovation can be regarded as the ability to simultaneously pursue both exploitative (refinement-led) and exploratory (discovery-led) innovation activities [30]. Generally speaking, enterprise innovation entails both exploitative and exploratory innovation, which help firms achieve short-term and long-term performance, respectively [31]. In the long-term development of firms, exploitative and exploratory innovation are mutually exclusive and interdependent, and ambidextrous innovation is essential for building sustainable competitive advantage [32]. Although there are differences in the implementation process of exploitative and exploratory innovation, they both have unpredictability and long periodicity. Factors such as enterprise absorptive capacity [33], strategic capacity [34], big data capability [32], network capital [35], distributed leadership [36], and servitization [37] all have significant impacts on ambidextrous innovation of enterprises. Moreover, there are both empowering and enabling effects in the process of digitalization driving enterprise innovation [38]. However, research on the influencing factors of ambidextrous innovation in enterprises has not fully considered digitalization's empowering and enabling effects. Therefore, it is necessary to study the relationship between digitalization and ambidextrous innovation in enterprises from the perspective of empowering and enabling.

Based on these findings, the paper constructs a research framework of "regional digitalization–enterprise digitalization–enterprise ambidextrous innovation". It focuses on Chinese manufacturing enterprises to analyze the relationship between digitalization and ambidextrous innovation from the perspective of empowering and empowering. Theoretical analysis and practice are the main reasons for this research framework. On the one hand, regional digitalization and enterprise digitalization can have an interactive impact on enterprise innovation, and there are also exploitative and exploratory innovation activities in enterprises. In the context of multilevel interactions, the empowering and enabling effects of digitalization on different innovations are not yet clear. Therefore, by providing insight into this issue, we can better understand the complex effects of digitalization on enterprise innovation. On the other hand, the Chinese government has actively promoted digital development in recent years, and the level of regional digitalization has significantly improved [39]. A favorable external environment has been created for firms' digital transformation and innovation development. In addition, China's manufacturing sector is complete and ranks first in the world in terms of scale. China is committed to promoting the development of intelligence in the manufacturing industry. Therefore, exploring the relationship between digitalization and enterprise ambidextrous innovation based on China's manufacturing experience has important implications for the development of digitalization and innovation in other emerging economies.

Compared with the existing literature, the contributions of this study are three-fold. Firstly, from the perspective of empowering and enabling, this paper explores the multilevel impact of regional digitalization and enterprise digitalization on enterprise innovation. It provides a new perspective for studying digitalization and enterprise innovation. Secondly, based on organizational ambidexterity, this paper divides enterprise innovation into exploitative and exploratory and examines the impact of network infrastructure construction, digital technology development, digital talent reserve, and digital technology application on enterprise ambidextrous innovation. It expands the research content of digitalization and enterprise innovation. Thirdly, by incorporating firm size into the research framework, the paper explores the moderating role of firm size in the relationship between digitalization and enterprise ambidextrous innovation. This helps us to have a deeper understanding of digitalization and enterprise innovation.

The remainder of this paper is organized as follows: Section 2 presents the theoretical analysis and research hypotheses; Section 3 describes the research design, including data source, definition of variable, and model design; Section 4 presents the empirical results and analysis; finally, the conclusions, the implications, limitations and prospects are presented in the last section.

2. Theoretical Analysis and Research Hypothesis

2.1. Theoretical Analysis

According to the theory of technological innovation, enterprises will face two questions when using new technologies for innovation. First, what does the new technology bring? Second, what can be carried out with the latest technology? Digitalization, based on the application of digital technology, continues to enrich the answers to the above questions. Under the digital economy, digital technology empowers all users, and participants can use the same information technology for different creative activities [40]. Therefore, digitalization can lead to value creation such as efficiency, convergence, and generation [41], which can significantly impact enterprise innovation in terms of empowering and enabling [38]. Generally speaking, empowering focuses on the same capabilities that something provides to the subject, and enabling emphasizes the unique creation of the subject using their abilities and initiative. In terms of digitalization empowering, the widespread use of digital technologies has dramatically improved social productivity. Digitalization empowers enterprises' structure, psychology, and resources [40], improving innovation efficiency by shortening R&D cycles and saving resources [41]. In terms of digitalization enabling, the availability of digital technologies brings convergence and generative innovation [41,42]. By exercising their own initiative, enterprises can apply digital technologies to all aspects to create new models and value [27,28]. From the perspective of the digitalization subject, regional digitalization development empowers enterprises in the region to use digital technologies conveniently, contributing the vast majority of the empowering effect. In addition, the enterprises' own digitalization development and their creativity determines the size of the enabling effect. Thus, we regard the positive effect of regional digitalization development on enterprise innovation as the empowering effect and the positive effect of enterprises' own digital development on their innovation as the enabling effect.

Digitalization can be understood at the regional and firm levels. At the regional level, regional digitization refers to the digital transformation of various social organizations that maintain the stable operation of the national economy [43]. The use of digital technology integrates business and operational models and improves service efficiency and quality. It changes the process of social development and economic operation [44]. Specifically, the application of digital technologies is a gradual process, and the regional digitalization level is closely related to digital foundation, digital input, and digital application [45]. First, network infrastructure construction is the basis for regional digital development. For example, big data analytics is typical of digital technologies, and its effects depend on information infrastructure governance [46]. Second, digital technology is leading the global technological revolution and industrial transformation [47]. Thus, the development of digi-

tal technology provides the technological impetus for regional digitalization. Third, digital talent is an essential carrier of skill application and knowledge innovation, and digital talent reserve can provide human resources for regional digitalization [48]. Fourth, effective technology needs to play an essential role in social practice. Digital technology application is not only a true reflection of the level of regional digitalization, but it also provides a sustained impetus for the development of regional digitalization. For example, cloud computing and blockchain technology can help enterprises achieve intelligent manufacturing, and the combination of intelligent manufacturing and network physical system can further stimulate the application of digital twin technology [49]. Based on the above, this paper measures the comprehensive level of regional digitalization from four dimensions: network infrastructure construction, digital technology development, digital talent reserve, and digital technology application.

At the firm level, digitalization is diverse. On the one hand, digitization refers to converting information into digital resources [50], such as converting audio, video, and related information into digital streams. On the other hand, digitalization uses digital technologies to create or harvest value. In this process, enterprises gradually develop a digital-centric business model and undergo business reinvention and organizational change [51,52]. In contrast, digitization is only one type of business model for firms. It does not change the enterprise's original business model and development strategy [53]. However, digitalization is more extensive. It is a comprehensive change implemented by enterprises to embrace digital technology's new opportunities and needs [53]. In the actual operation of enterprises, the purpose of using digital technology is to pursue unique value creation. Moreover, the improvement in enterprise digitalization level is a long-term process. Therefore, following the definition by Parida et al. [3], this paper considers enterprise digitalization as the utilization of digital technologies by companies to innovate business models, generate new revenue sources, and create additional value.

2.2. Research Hypothesis

2.2.1. Empowering Effect of Regional Digitalization on Enterprise Ambidextrous Innovation

Regional digitalization includes network infrastructure construction, digital technology development, digital talent reserve, and digital technology application. Therefore, regional digitalization development facilitates the formation of a digital ecosystem in which members can enjoy greater digital benefits. For instance, within digital ecosystems, digitalization creates new opportunities, facilitates the rapid dissemination of knowledge, and leads to a supportive environment, thus empowering each intra-regional member [40].

In terms of enterprise innovation, the impact of regional digitalization on ambidextrous innovation of enterprises includes increasing firms' innovation investment, improving inter-firm interactions, increasing firms' intellectual capital, and expanding knowledge spillovers. First, network infrastructure has significant network effects and positive externalities [54]. Network infrastructure construction can reduce the information search and transaction costs of enterprises and reduce the investment in non-productive activities of enterprises. As a result, enterprises can devote sufficient capital and time to R&D activities, and there will be a significant increase in the number of exploitative and exploratory innovations of enterprises. Second, digital technology helps to expand the methods of information exchange among enterprises. Thus, the innovation network of enterprises in the region with high levels of digital technology development will have higher connectivity [55]. By leveraging digital technologies, enterprises can upgrade existing technologies and products to increase the output of exploitative innovation. At the same time, enterprises can accelerate the integration of heterogeneous knowledge and promote exploratory innovation. Third, digital talents are the most intelligent and active elements in creation [48]. The regional digital talent reserve can empower enterprises with more intellectual capital. As a result, enterprises can have more inspiration for innovation and carry out more ambidextrous innovation activities. Fourth, digital technologies such as big data and artificial intelligence are being integrated into enterprises' production and operation processes [49]. Digital

technology application can stimulate the positive externality of knowledge and technology in the process of dissemination and application. Therefore, in regions with a high level of regional digital technology adoption, enterprises can enjoy more digital benefits, accelerate new ideas, and develop high-quality exploratory innovation. In addition, enterprises can also leverage more user information for exploitative innovation.

Moreover, the empowering effects of network infrastructure construction, digital technology development, digital talent reserve, and digital technology application on enterprise innovation will differ because they have different empowering mechanisms. Enterprise innovation is a complex activity with long cycles and high risks. Digital talent can significantly improve enterprises' absorptive and adaptive capacity [56]. Therefore, digital talent reserve will have a more significant positive effect on enterprise innovation. Based on this, the following hypotheses are proposed:

Hypothesis 1a (H1a). *Regional digitalization can promote exploitative and exploratory innovation in manufacturing enterprises.*

Hypothesis 1b (H1b). *Regional digital talent reserve will significantly impact manufacturing enterprises' exploitative and exploratory innovation more than network infrastructure construction, digital technology development, and digital technology application.*

2.2.2. Empowering Effect of Regional Digitalization on Enterprise Ambidextrous Innovation

Driven by digital technologies, data, knowledge, and other innovation factors are connected brighter and closer, and it is increasingly crucial for enterprises to leverage the enabling effect of digitalization for innovation [38]. Specifically, using digital technologies can improve the dynamic capabilities of enterprises [57]. The unique abilities of each enterprise to perceive, integrate, and transform will provide more possibilities for ambidextrous innovation.

The impact of enterprise digitalization on exploitative innovation includes stimulating innovation potential, optimizing innovation processes, and accelerating product iteration. Firstly, enterprise digitalization can inspire the potential value of existing innovation resources. Digital technology application enable enterprises to access, share and reorganize innovation resources more efficiently [58]. In the context of digital technology being fully applied to enterprise innovation activities, innovation elements can be linked and combined in new ways to generate new uses, inspiring new ideas for exploitative innovation in enterprises. Secondly, enterprise digitalization can lead to innovation process optimization through technology upgrades. For example, digital twin technology can make the innovation process no longer completely dependent on physical experiments [49]. Based on the scalability of digital technology, the existing technology of enterprises can be upgraded intelligently, enabling the continuous optimization of the enterprise innovation process. In this process, there will be more and more exploitative innovations. Finally, enterprise digitalization can provide new momentum for product renewal. The self-growing nature of digital technology allows products to be continuously updated based on user feedback even after they have been designed [42]. Users' opinions on products are more relevant and practical. Enterprises can identify product shortcomings and implement improvements by collecting, analyzing, and applying user feedback. As a result, enterprises will implement more exploitative activities and achieve effective innovation results.

The impact of enterprise digitalization on explorative innovation includes leveraging new opportunities, integrating new knowledge, and developing new products. First, enterprise digitalization improves the ability of enterprises to identify and apply innovation opportunities. Currently, the external environment of enterprises is changing rapidly. Digitalization can help enterprises improve their digital scanning capabilities to identify innovation opportunities [59]. It can provide more possibilities for exploratory innovation in companies. Second, enterprise digitalization accelerates the absorption and convergence of new knowledge. Digital technologies have broken the boundaries of time and space [60]. Through extensive use of digital technology, enterprises can adopt more communication

channels for external learning. In addition, knowledge and information will also be deeply utilized through the professional application of digital technology. As a result, extensive learning and professional application can promote the integration of heterogeneous knowledge, and enterprises will have more ideas to carry out exploratory innovation. Finally, enterprise digitalization improves the willingness and performance of new product development. Digital technologies, such as virtual customer environments (VCEs), allow customers to participate in the design of new products [9,61], inspiring enterprises to expand in new business areas. Moreover, technology cooperation between enterprises can be more efficient and less costly with the help of digital technology [55,62], and the exploratory innovation of enterprises will proceed more smoothly. Based on this, the following hypotheses are proposed:

Hypothesis 2a (H2a). *Enterprise digitalization can significantly improve exploitative innovation in manufacturing enterprises.*

Hypothesis 2b (H2b). *Enterprise digitalization can significantly improve exploratory innovation in manufacturing enterprises.*

2.2.3. Transformation from Empowering to Enabling of Digitalization

At present, the digital transformation of traditional enterprises has become a key path to adapt to changes in the external environment, and the effect of enterprise digitalization is closely dependent on regional digitalization. For example, in regions with higher levels of digitalization, the digital transformation of enterprises will be more effective, and enterprises can carry out more innovative activities by using digital technology. In other words, regional digitalization can improve enterprise digitalization to promote the ambidextrous innovation of enterprises. That is, the empowering effect of regional digitalization can be converted into the enabling effect of enterprise digitalization in innovation.

Specifically, regional digitalization will improve enterprise digitalization in the following aspects. First, network infrastructure construction lays the foundation for the digital transformation of enterprises [63], which can accelerate the intelligent transformation of enterprises. For example, the improvement in network infrastructure will increase the motivation and creativity of society to integrate technological change [14], and the development of the digital industry can provide a solid guarantee for the circulation of data elements and the application of digital technology. Second, digital technology is an essential external driver of digital transformation in enterprises [52]. Digital technology development can significantly enhance the level of digital technology in the region, prompting enterprises to increase the application of digital technology. Therefore, in regions with high levels of digital technology development, the digital transformation of enterprises will continue to deepen, and the digital level of enterprises will be rapidly improved. Third, digital talents have the ability to analyze data, adapt to new environments and solve new problems, and regional digital talent reserve can provide enterprises with more complex talents. By solving management and technical problems in the digital transformation process, enterprises can achieve more digital transformation results. Fourth, digital technology application can bring businesses digital convenience and new user needs. As a result, enterprises will face greater competition in the market. In pursuit of more digital benefits, enterprises will continue to promote a new round of digital transformation [52,64].

In conclusion, through the promotion and acceleration of regional digitalization, the level of enterprise digitalization can be rapidly improved, and the digitalization enabling effect will be released more effectively. Enterprise digitalization will be driven by external factors such as digital technology development and market competition and demand, as well as internal factors such as leaders and employees [2,52]. Digital talent is not only the practitioner of digital transformation for enterprises but also the key for internal and external factors to play a driving role. Therefore, compared with network infrastructure construction, digital technology development, and digital technology application, the digi-

tal talent reserve will have a more prominent role in promoting the digital transformation of enterprises. Based on this, the following hypotheses are proposed:

Hypothesis 3a (H3a). *Regional digitalization can enhance the level of enterprise digitalization.*

Hypothesis 3b (H3b). *Regional digital talent reserve will significantly impact manufacturing enterprise digitalization more than network infrastructure construction, digital technology development, and digital technology application.*

2.2.4. Moderating Role of Firm Size

According to the "Schumpeterian hypothesis", large-scale enterprises have the advantages of economies of scale, anti-risk solid ability, and abundant resources, and their technological innovation will be more effective. However, some scholars believe that small-scale enterprises with less bureaucracy can generate more product and process innovation by implementing new management practices [65]. It can be seen that firm size plays a vital role in the firm's innovation process, and the role can vary significantly depending on the type of firm and innovation. Currently, it is unclear what role enterprise scale plays in the relationship between digitalization and ambidextrous innovation of manufacturing enterprises. Therefore, this paper explores the moderating role of firm size in three separate paths. The three paths are "regional digitalization–enterprise ambidextrous innovation", "enterprise digitalization–enterprise ambidextrous innovation" and "regional digitalization–enterprise digitalization". This will help us to have a more comprehensive understanding of the role of firm size in the innovation process of manufacturing enterprises in the digital age.

First, in the process of the influence of regional digitalization on enterprise ambidextrous innovation, digitalization has an empowering effect on enterprise innovation. Enterprises tend to invest in innovation activities only when making regular profits [66], and enterprises with more innovative activities can enjoy more digitalization empowering effects. Large-scale manufacturing enterprises can usually make more profits than small and medium-scale enterprises. As a result, they can conduct more R&D activities, and the digitalization empowering effect on their innovation will be stronger. Second, in the process of the influence of enterprise digitalization on enterprise ambidextrous innovation, digitalization has an enabling effect on enterprise innovation. Digital transformation has a more significant positive effect on the innovation activities of high-survivability enterprises [66]. Because of higher resource endowments and greater viability, the digitalization enabling effect of larger-scale enterprises will be better unleashed. Third, in the process of the influence of regional digitalization on enterprise digitalization, digitalization achieves the conversion of empowering effect to enabling effect. Digital transformation is a long-term, tortuous, and uncertain activity [67]. Large-scale enterprises have a higher level of technology, so they can quickly respond to changes in the technological environment and become pioneers and implementers of digital transformation. Therefore, the positive effect of regional digitalization on large-scale enterprise digitalization will be more significant. Based on this, the following hypotheses are proposed:

Hypothesis 4a (H4a). *The positive effect of regional digitalization on exploitative and exploratory innovation in manufacturing enterprises is more significant when the firm size is more extensive.*

Hypothesis 4b (H4b). *The positive effect of enterprise digitalization on exploitative and exploratory innovation in manufacturing enterprises is more significant when the firm size is more extensive.*

Hypothesis 4c (H4c). *The positive effect of regional digitalization on manufacturing enterprise digitalization is more significant when the firm size is more extensive.*

In conclusion, the research model constructed in this paper is shown in Figure 1.

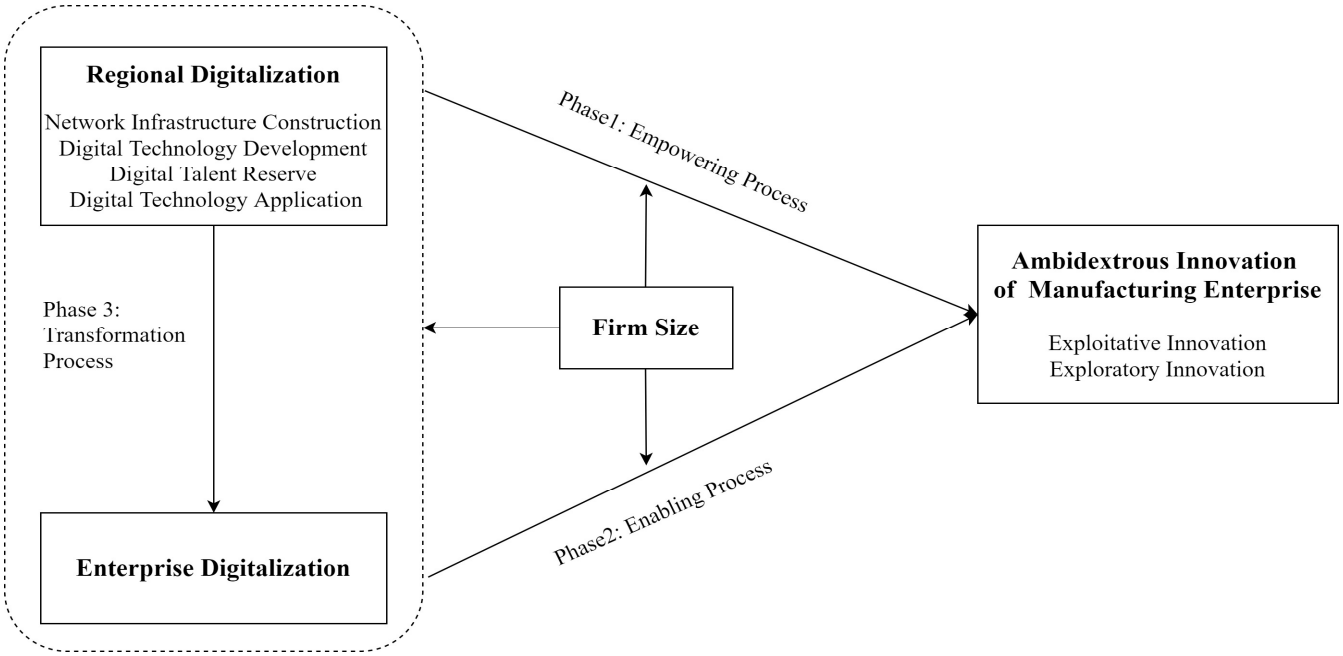

Figure 1. Research model.

3. Research Design

3.1. Data Source

This study selected A-share companies listed on the Shanghai and Shenzhen stock markets from 2011 to 2021 as the research sample. The data sources are as follows: (1) the patent data reflecting the ambidextrous innovation performance of enterprises were obtained from the Chinese Research Data Services (CNRDS); (2) the measurement data of regional digitalization and the control variable data at the regional level were obtained from the China statistical yearbook, among others. Given the availability and completeness of the data, this paper measured the digitalization level of 30 provinces in China, except for Tibet, Taiwan, Hong Kong, and Macau; (3) the data on enterprise digitalization were obtained from annual reports of listed companies, and text analysis was conducted using keywords. Other financial data were obtained from the China Stock Market and Accounting Research (CSMAR) database. In order to improve the data quality, the samples of ST and *ST companies and observations with missing data were excluded. Moreover, all continuous variables were winsorized by a 1% level to control for extreme data values. In total, 19,527 firm-year observations were obtained.

3.2. Definition of Variable

3.2.1. Explained Variables

Exploitative innovation can be understood as improving, implementing, and extending existing knowledge and products by enterprises; exploratory innovation can be defined as the discovery, creation, and pursuit of new knowledge and products by enterprises [30,33]. Because the number of patents is less susceptible to managerial preferences and is relatively objective, it has become a valid indicator of innovation performance. Compared with utility models and design patents, invention patents present new technical solutions for products and methods with higher technical content and more excellent innovation value. Therefore, referring to the treatment by Li and Zheng [68], we use the natural logarithm of the number of authorized utility model and design patents authorization plus one to measure enterprise exploitative innovation. Meanwhile, we use the natural logarithm of the number of authorized invention patents plus one to measure enterprise exploitative innovation.

3.2.2. Explanatory Variables

Regional digitalization: Regional digitalization reflects the overall level of digital development in a region at present. A single indicator cannot comprehensively reflect the digitalization level of regions, and there is no uniform standard to measure the digitalization level of regions. Therefore, this paper constructs a comprehensive indicator to measure the level of regional digitalization through network infrastructure construction (Rdi-nic), digital technology development (Rdi-dtd), and digital talent reserve (Rdi-dtr), and digital technology application (Rdi-dta). The index system of regional digitalization is shown in Table 1.

Table 1. Regional digitalization index system.

Primary Indicators	Secondary Indicators	Tertiary Indicators	Source of Data
Regional digitalization (Rdi)	Network infrastructure construction (Rdi-nic)	Total fixed-asset investment in information transmission, computer services, and software industry (million CNY)	China Statistical Yearbook
		The length of fiber optic cable (kilometer)	China Statistical Yearbook
		The number of Internet users in the province/total resident population in the province	Statistical Report on the Development of the Internet in China
		The number of Internet users in the province (million people)	China Statistical Yearbook
	Digital technology development (Rdi-dtd)	The contract amount of technology flow to the geographical area (million CNY)	China Statistical Yearbook on Science and Technology
		Introduction funds for regional high-tech industry technology (million CNY)	China Statistical Yearbook on Science and Technology
		Funds for the transformation of regional high-tech industry technology (million CNY)	China Statistical Yearbook on High Technology Industry
		Internal expenditure on R&D expenses in the electronics and communications equipment manufacturing industry (million CNY)	China Statistical Yearbook on High Technology Industry
		Internal expenditure on R&D expenses in the electronic computer and office equipment manufacturing industry (million CNY)	China Statistical Yearbook on High Technology Industry
	Digital talent reserve (Rdi-dtr)	The number of employees in the information transmission and software industry (million people)	China Statistical Yearbook
	Digital technology application (Rdi-dta)	The number of software enterprises (people)	China Statistical Yearbook on High Technology Industry
		Revenue of software business (million people)	China Statistical Yearbook on Electronic Information Industry
		Export sales revenue of new products in the high-technology industry (million people)	China Statistical Yearbook on Electronic Information Industry

In order to objectively measure the digitalization level of each province in China, we adopt the entropy value method to scientifically assign indicator weights and add a time variable to determine the indicator weights. The model is set as follows:

$$X'_{tij} = \frac{X_{tij} - \min\{X_{tij}\}}{\max\{X_{tij}\} - \min\{X_{tij}\}} \quad (1)$$

$$Y_{tij} = X'_{tij} / \sum_t \sum_i X'_{tij} \quad (2)$$

$$e_j = -k \sum_t \sum_i Y_{tij} \ln(Y_{tij}) \quad (3)$$

$$g_j = 1 - e_j \quad (4)$$

$$W_j = g_j / \sum_j g_j \quad (5)$$

$$DIG_{ti} = \sum_j \left(W_j X'_{tij} \right) \quad (6)$$

In equation model (1) to equation model (6), t represents the year, i represents the province, and j represents the indicator. The calculation process is as follows: (1) and (2) calculate the standardized results of the indicator; (3) calculates the entropy of the jth indicator; (4) calculates information entropy redundancy; (5) calculates indicator weights; and (6) calculates the digitalization level of each province.

Enterprise digitalization: An enterprise's digitalization level is directly proportional to the degree of its digital transformation. Therefore, we evaluate the level of enterprise digitalization based on the extent of enterprise digital transformation. The frequency statistics of words related to "digital transformation" in the annual reports of enterprises can effectively reflect the strategic planning and implementation intensity of digital transformation, which is a scientific and feasible quantitative research method [69]. Therefore, according to the method of measuring the digital transformation degree of enterprises by Zhao et al. [70], we measure the level of enterprise digitalization in four dimensions: digital technology application, Internet business model, intelligent manufacturing, and modern information system. And we used text analysis to count each keyword's frequency and takes the natural logarithm of the total number of frequencies as the index of enterprise digitalization.

3.2.3. Other Variables

Moderating variable: Firm size is the moderating variable in this paper. The total number of assets owned by an enterprise can provide a more accurate reflection of the enterprise's production scale and resource endowment advantages. A more considerable total asset value indicates a larger enterprise size. Therefore, according to the treatment by Liu et al. [22], we use the natural logarithm of the total assets to proxy for firm size.

Control variables: To accurately analyze digitalization's impact on manufacturing enterprise ambidextrous innovation, we control for variables that may affect enterprise ambidextrous innovation from the firm and regional levels. The control variables at the firm level include enterprise age and enterprise growth, among. The control variables at the regional level include economic development, government support for science and technology, and others. The specific definition of each variable is shown in Table 2.

Table 2. Variable definitions.

Variable Type	Variable Name	Variable Symbol	Variable Definition
Explained variable	Exploitative innovation	Exploi	Natural logarithm of the number of authorized utility model and design patents invention patents +1 of the enterprise in the current year
	Exploitative innovation	Explor	Natural logarithm of the number of authorized invention patents +1 of the enterprise in the current year
Explanatory variable	Regional digitalization	Rdi	The digital comprehensive level of the region where the enterprise was located in the current year
	Network infrastructure construction	Rdi-nic	The level of network infrastructure construction of the region where the enterprise was located in the current year
	Digital technology development	Rdi-dtd	The level of digital technology development of the region where the enterprise was located in the current year
	Digital talent reserve	Rdi-dtr	The level of digital talent reserve of the region where the enterprise was located in the current year
	Digital technology application	Rdi-dta	The level of digital technology application of the region where the enterprise was located in the current year
	Enterprise digitalization	Edi	The natural logarithm of word-frequency count of keywords related to digital transformation in the annual report of the enterprise in the current year
Moderating variable	Firm size	Size	Natural logarithm of the enterprise's total assets in the current year
Firm-level control variable	Enterprise age	Age	Natural logarithm of the current year minus the year of establishment
	Enterprise growth	Gro	Increase in operating income/Operating income of the previous year
	Debt–asset ratio	Dar	Total liabilities at the end of the year/Total assets at the end of the year
	Ownership concentration	Share	The shareholding ratio of the first largest shareholder in the current year
	Ownership type	Ow	It is 1 when the enterprise is a state-owned enterprise; otherwise, it is 0
Regional-level control variable	Economic development level	GDP	Natural logarithm of the GDP per capita for each province in the current year
	Government support for science and technology	Gov	Local government expenditure on science and technology in the current year/Local government general budget expenditure in the current year
	Industry Structure	Str	Value added of tertiary industry/Value added of secondary industry for each province in the current year

3.3. Model Design

In order to verify the impact of regional digitalization on manufacturing enterprise ambidextrous innovation and the impact of enterprise digitalization on manufacturing enterprise ambidextrous innovation, the total effect model was set in this study as follows:

$$Inno_{it} = \alpha_0 + \alpha_1 Rdi_{it} + \sum \gamma Control_{it} + \mu_t + \varepsilon_{it} \quad (7)$$

$$Inno_{it} = \alpha_0 + \alpha_1 Edi_{it} + \sum \gamma Control_{it} + \mu_t + \varepsilon_{it} \quad (8)$$

In equation model (7) and equation model (8), $Inno_{it}$ represents exploitative and exploitative innovation of enterprises, respectively. The core explanatory variable Rdi_{it} represents the level of digitalization of the previous, core explanatory variable Edi_{it} represents the level of digitalization of enterprises, $Control_{it}$ represents the control variables, μ_t controls the time-fixed effect, and ε_{it} is the random-error term.

In order to investigate the transformation mechanism from regional digitalization empowering to enterprise digitalization enabling, the following model was set in this study:

$$Edi_{it} = \alpha_0 + \alpha_1 Rdi_{it} + \sum \gamma Control_{it} + \mu_t + \varepsilon_{it} \quad (9)$$

$$Inno_{it} = \alpha_0 + \alpha_1 Rdi_{it} + \beta Edi_{it} + \sum \gamma Control_{it} + \mu_t + \varepsilon_{it} \quad (10)$$

Equation model (7) examined the direct effect of regional digitalization on enterprise digitalization, and equation model (7), equation model (9), and equation model (10) form a mediating effects model. Using the mediating-analysis model, we can investigate enterprise digitalization's role in the relationship between regional digitalization and manufacturing enterprise ambidextrous innovation. This model can help us to understand the transformation process from digitalization enabling effects to enabling effects.

Meanwhile, as a further check of the moderating effect of firm size between regional digitalization, enterprise digitalization, and manufacturing enterprise ambidextrous innovation, the following moderating-analysis model was set in this study:

$$Inno_{it} = \alpha_0 + \alpha_1 Rdi_{it} + \beta Size_{it} + \chi Rdi_{it} * Size_{it} + \sum \gamma Control_{it} + \mu_t + \varepsilon_{it} \quad (11)$$

$$Inno_{it} = \alpha_0 + \alpha_1 Edi_{it} + \beta Size_{it} + \chi Edi_{it} * Size_{it} + \sum \gamma Control_{it} + \mu_t + \varepsilon_{it} \quad (12)$$

$$Edi_{it} = \alpha_0 + \alpha_1 Rdi_{it} + \beta Size_{it} + \chi Rdi_{it} * Size_{it} + \sum \gamma Control_{it} + \mu_t + \varepsilon_{it} \quad (13)$$

In equation model (11) to equation model (13), $Size_{it}$ represents the firm size, which is the model's moderating variable. Equation model (11) judges the moderating effect of firm size through the interaction between regional digitalization and manufacturing enterprise ambidextrous innovation. Equation model (12) judges the moderating effect of firm size through the interaction between enterprise digitalization and manufacturing enterprise ambidextrous innovation. Equation model (13) judges the moderating effect of firm size through the interaction between regional digitalization and enterprise digitalization.

4. Theoretical Analysis and Research Hypothesis

4.1. Descriptive Statistics

Table 3 presents the results of descriptive statistics for the main variables. The mean value for Exploi is 1.564, with a standard deviation of 1.386 and a maximum value of 5.730. These findings suggest significant variations in exploitative innovation amongst manufacturing enterprises in China. Similarly, the statistical analysis of Explor reveals notable differences in exploratory innovation amongst manufacturing enterprises. Additionally, the mean and median values of exploitative innovation exceed those of exploratory innovation, indicating that the overall level of exploratory innovation within enterprises falls short of

that of exploitative innovation. This suggests that exploitative and exploratory innovation exhibit significant variability within manufacturing enterprises. Furthermore, the mean value of regional digitalization is 0.212, and the maximum value is 0.879, indicating that the overall level of regional digitalization is not high and that there is a significant imbalance in the development of regional digitalization in China. The mean value of enterprise digitalization is 2.719, the median value is 2.708, and the maximum value is 5.584, indicating that manufacturing enterprises have generally carried out digital transformation at the overall level. However, there are significant differences in the level of digitalization among enterprises. The distributions of the descriptive statistics values of the other variables are reasonable. For reasons of the length of this paper, they are not described.

Table 3. Descriptive statistics.

Varible	Obs.	Mean	Standard Deviation	Median	Minimum	Maximum
Exploi	19,527	1.564	1.386	1.517	0	5.730
Explor	19,527	0.873	0.693	1.063	0	4.595
Rdi	19,527	0.212	0.148	0.199	0.013	0.879
Edi	19,527	2.719	2.708	1.204	0	5.584
Size	19,527	21.971	21.811	1.163	19.420	25.440
Age	19,527	17.218	17.000	5.585	5	32
Gro	19,527	0.086	0.101	0.253	−0.924	0.846
Dar	19,527	0.387	0.375	0.195	0.050	0.883
Share	19,527	33.699	31.630	14.049	9.090	73.130
Ow	19,527	0.267	0.000	0.442	0	1
GDP	19,527	11.136	11.152	0.438	10.164	12.065
Gov	19,527	0.035	0.038	0.017	0.008	0.068
Str	19,527	1.408	1.174	0.870	0.688	5.234

Before conducting the model's regression analysis, Pearson correlation coefficients are estimated for the variables. The results indicate that regional and enterprise digitalization are significantly and positively correlated with exploitative and exploratory innovation. Furthermore, the maximum variance inflation factor (VIF) value for each variable is 3.78, with a mean value of 1.75. These findings suggest no significant multicollinearity among the variables in the model.

4.2. Empirical Analysis

4.2.1. Regional Digitalization and Ambidextrous Innovation in Manufacturing Enterprises

The paper initially verifies the relationship between regional digitalization and enterprise ambidextrous innovation. The results of this relationship can be found in Table 4. Columns (1) and (2) present the regression results of regional digitalization on exploitative and exploratory innovation of enterprises, with the regression models excluding control variables. Columns (3) and (4) present the regression results after adding firm-level control variables. Furthermore, columns (5) and (6) report the regression results after adding firm-level and regional-level control variables. As the control variables gradually increase, the coefficient of regional digitalization remains positive and significant at the 1% level. This indicates that regional digitalization has a significant positive impact on both exploitative and exploratory innovation of manufacturing enterprises, and this conclusion is relatively robust. Therefore, Hypothesis 1a is verified. At the same time, the data in columns (5) and (6) show that the Gro and the Gov have a positive effect on both exploitative and exploratory innovation of manufacturing enterprises at the significant level of 1%, which indicates that resources support play an essential role in all types of innovation in manufacturing enterprises. On the one hand, better-growing firms have a higher innovation orientation and more capital. By increasing their investment in R&D activities, they can carry out more exploitative and exploratory innovation activities. On the other hand, government support

for science and technology can create a favorable innovation environment for enterprises. Enterprises will achieve more innovative results by enjoying financial and policy support.

Table 4. Empirical results of the relationship between regional digitalization and ambidextrous innovation in manufacturing enterprises.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	**Exploi**	**Explor**	**Exploi**	**Explor**	**Exploi**	**Explor**
Rdi	0.825 ***	0.467 ***	0.899 ***	0.617 ***	0.410 ***	0.437 ***
	(14.319)	(11.519)	(15.715)	(15.621)	(5.154)	(7.903)
Size			0.246 ***	0.267 ***	0.257 ***	0.266 ***
			(22.351)	(35.099)	(23.399)	(34.866)
Age			−0.030 ***	−0.019 ***	−0.032 ***	−0.018 ***
			(−14.065)	(−12.497)	(−14.742)	(−12.285)
Gro			0.138 ***	0.105 ***	0.133 ***	0.101 ***
			(3.234)	(3.562)	(3.127)	(3.423)
Dar			0.058	−0.281 ***	0.009	−0.264 ***
			(0.916)	(−6.434)	(0.141)	(−6.035)
Share			0.005 ***	−0.001 ***	0.005 ***	−0.002 ***
			(6.983)	(−2.725)	(6.681)	(−2.922)
Ow			−0.077 ***	0.102 ***	−0.032	0.107 ***
			(−2.877)	(5.507)	(−1.163)	(5.683)
GDP					−0.129 ***	−0.014
					(−2.655)	(−0.428)
Gov					10.039 ***	3.593 ***
					(7.717)	(3.981)
Str					−0.196 ***	0.006
					(−12.844)	(0.545)
Constant	1.275 ***	0.622 ***	−3.877 ***	−4.826 ***	−2.721 ***	−4.736 ***
	(30.854)	(21.406)	(−16.976)	(−30.587)	(−4.963)	(−12.451)
Year_FE	YES	YES	YES	YES	YES	YES
N	19,527	19,527	19,527	19,527	19,527	19,527
Adj-R^2	0.025	0.017	0.070	0.096	0.080	0.097

Notes: The values between parentheses are t-statistics. *** represents significance levels of 1%. All variables are as previously defined.

In addition, this paper examines the effects of four subdimensions of regional digitalization on enterprise ambidextrous innovation, and the regression results are shown in Table 5. Columns (1) and (2) report the core results of testing the relationship between "regional network infrastructure construction and enterprise ambidextrous innovation". The regression coefficients of Rdi-nic on Exploi and Explor are 10.913 and 7.635, respectively, both significant at the 1% level. Columns (3) and (4) report the core results of testing the relationship between "regional digital technology development and enterprise ambidextrous innovation". The regression coefficients of Rdi-dtd on Exploi and Explor are 0.533 and 0.635, respectively, both significant at the 1% level. Columns (5) and (6) report the core results of testing the relationship between "regional digital talent reserve and enterprise ambidextrous innovation". The regression coefficients of Rdi-dtr on Exploi and Explor are 11.035 and 9.163, respectively, both significant at the 1% level. Columns (7) and (8) report the core results of testing the relationship between "regional digital technology application and enterprise ambidextrous innovation". The regression coefficients of Rdi-dta on Exploi and Explor are 1.251 and 1.274, respectively, both significant at the 1% level. The results suggest that regional network infrastructure construction, digital technology development, digital talent reserve, and digital technology application significantly promote both the exploitative and exploratory innovation of manufacturing enterprises. Furthermore, the four variables, namely network infrastructure construction, digital technology development, digital talent reserve, and digital technology application, have been standardized, and the research samples used for these models are consistent. Thus, comparing the size of the regression coefficients, the order of coefficient magnitudes indicates that the regional digital talent reserve has played the most significant promoting role. As a result, Hypothesis 1b is validated.

Table 5. Subdimensions of regional digitalization and ambidextrous innovation in manufacturing enterprises.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	**Exploi**	**Explor**	**Exploi**	**Explor**	**Exploi**	**Explor**	**Exploi**	**Explor**
Rdi-nic	10.913 ***	7.635 ***						
	(7.633)	(7.690)						
Rdi-dtd			0.533 ***	0.635 ***				
			(4.097)	(7.031)				
Rdi-dtr					11.035 ***	9.163 ***		
					(6.970)	(8.339)		
Rdi-dta							1.251 ***	1.274 ***
							(5.427)	(7.965)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Constant	−1.925 ***	−4.018 ***	−2.882 ***	−4.984 ***	−2.837 ***	−4.729 ***	−2.186 ***	−4.171 ***
	(−3.546)	(−10.656)	(−5.134)	(−12.798)	(−5.187)	(−12.456)	(−4.036)	(−11.100)
Year_FE	YES	YES	YES	YES	YES	YES	YES	YES
N	19,527	19,527	19,527	19,527	19,527	19,527	19,527	19,527
Adj-R^2	0.081	0.097	0.079	0.097	0.081	0.098	0.080	0.097

Notes: The values between parentheses are t-statistics. *** represents significance levels of 1%. The results of the control variable regressions are not reported in the table to ensure the article's brevity, and the subsequent tables are analogous.

4.2.2. Regional Digitalization, Enterprise Digitalization and Ambidextrous Innovation in Manufacturing Enterprises

Table 6 reports the results of testing the impact of enterprise digitalization on enterprise ambidextrous innovation and the impact of regional digitalization on enterprise digitalization. Columns (1) and (2) show that the regression coefficients of Edi on Exploi and Explor are 0.299 and 0.139, respectively, both significantly positive at the 1% level. It indicates that the enhancement of manufacturing enterprise digitalization level drives enterprise exploitative and exploratory innovation, and Hypothesis 2a and Hypothesis 2b are verified.

Table 6. Regional digitalization, enterprise digitalization and ambidextrous innovation in manufacturing enterprises.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable	**Exploi**	**Explor**	**Edi**	**Edi**	**Edi**	**Edi**	**Edi**
Edi	0.299 ***	0.139 ***					
	(31.675)	(20.853)					
Rdi			0.496 ***				
			(8.436)				
Rdi-nic				7.868 ***			
				(7.437)			
Rdi-dtd					0.826 ***		
					(8.589)		
Rdi-dtr						9.502 ***	
						(8.115)	
Rdi-dta							1.165 ***
							(6.833)
Controls	YES	YES	YES	YES	YES	YES	YES
Constant	−2.428 ***	−4.334 ***	−0.033	0.757 *	−0.433	0.021	0.588
	(−4.595)	(−11.647)	(−0.082)	(1.884)	(−1.045)	(0.051)	(1.468)
Year_FE	YES	YES	YES	YES	YES	YES	YES
N	19,527	19,527	19,527	19,527	19,527	19,527	19,527
Adj-R^2	0.124	0.114	0.202	0.201	0.202	0.201	0.201

Notes: The values between parentheses are t-statistics. ***, * represent significance levels of 1% and 10% respectively.

Column (3) examines the effect of regional digitalization on enterprise digitalization. The regression coefficients of Rdi on Edi is 0.496 at a 1% level, indicating that regional

digitalization positively impacts manufacturing enterprise digitalization. Therefore, Hypothesis 3a is verified. Columns (4), (5), (6), and (7) are the regression models of regional network infrastructure construction, digital technology development, digital talent reserve, and digital technology application on enterprise digitalization, respectively. The regression coefficients of their explanatory variables are 7.868, 0.826, 9.502, and 1.165, respectively, all significantly positive at the 1% level. Moreover, the coefficient of digital talent reserve is the largest. This indicates that regional network infrastructure construction, digital technology development, digital talent reserve, and digital technology application significantly increase the digitalization level of manufacturing enterprises, and the regional digital talent reserve plays a critical role. Therefore, Hypothesis 3b of the paper is verified.

To better understand the shift from regional digitalization empowering to enterprise digitalization enabling, this paper further examines the mediating role of enterprise digitalization through a recursive model, and the results of the test are shown in Table 7. Columns (1), (3), and (4) examine the mediating role of enterprise digitalization in the relationship between regional digitalization and enterprise exploitative innovation. The regression coefficients of regional digitalization in columns (1) and (3) are 0.410 and 0.496, respectively, both significantly positive at a 1% level. This indicates that regional digitalization significantly contributes to exploitative innovation and digitalization of manufacturing enterprises. Column (4) reveals the joint impact of regional and enterprise digitalization on enterprise exploitative innovation. These two variables both pass the significance test at a 1% level, and the regression coefficient of regional digitalization is 0.263, which is less than 0.410 in columns (1). It can be known that enterprise digitalization exerts a partial mediating effect in the relationship between regional digitalization and manufacturing enterprise exploitative innovation. Columns (2), (3), and (5) examine the mediating role of enterprise digitalization in the relationship between regional digitalization and enterprise exploratory innovation. And the mediating role of enterprise digitalization is also verified through the same analysis. The results above suggest that in promoting manufacturing enterprise ambidextrous innovation, the empowering effect of regional digitalization will be released by transforming into the enabling effect of enterprise digitalization, which also verifies the inevitability of transformation from empowering to enabling digitalization.

Table 7. Test results of the mediating effect of enterprise digitalization.

	(1)	(2)	(3)	(4)	(5)
Variable	**Exploi**	**Explor**	**Edi**	**Exploi**	**Explor**
Rdi	0.410 ***	0.437 ***	0.496 ***	0.263 ***	0.369 ***
	(5.154)	(7.903)	(8.436)	(3.379)	(6.741)
Edi				0.297 ***	0.136 ***
				(31.422)	(20.433)
Controls	YES	YES	YES	YES	YES
Constant	−2.721 ***	−4.736 ***	−0.033	−2.711 ***	−4.731 ***
	(−4.963)	(−12.451)	(−0.082)	(−5.068)	(−12.572)
Year_FE	YES	YES	YES	YES	YES
N	19,527	19,527	19,527	19,527	19,527
Adj-R^2	0.080	0.097	0.202	0.124	0.116

Notes: The values between parentheses are t-statistics. *** represents significance levels of 1%.

4.2.3. A Test of the Moderating Effect of Firm Size

In order to address the role of firm size in the relationship between digitalization and enterprise ambidextrous innovation, this paper examines the moderating role of firm size in three stages. The independent and moderating variables were centered to enhance the interpretability of regression coefficients. The results of the regression analysis are presented in Table 8.

Table 8. Test results of the moderating effect of firm size.

	(1)	(2)	(3)	(4)	(5)
Variable	**Exploi**	**Explor**	**Exploi**	**Explor**	**Edi**
Rdi	0.410 ***	0.438 ***			0.498 ***
	(5.148)	(7.940)			(8.466)
Edi			0.299 ***	0.142 ***	
			(31.591)	(21.439)	
Size	0.257 ***	0.267 ***	0.216 ***	0.240 ***	0.139 ***
	(23.373)	(35.003)	(19.899)	(31.443)	(17.115)
Rdi×Size	−0.048	0.180 ***			0.160 ***
	(−1.034)	(5.654)			(4.711)
Edi×Size			−0.003	0.050 ***	
			(−0.404)	(9.494)	
Controls	YES	YES	YES	YES	YES
Constant	3.018 ***	1.201 ***	3.118 ***	1.482 ***	3.111 ***
	(6.083)	(3.492)	(6.496)	(4.395)	(8.487)
Year_FE	YES	YES	YES	YES	YES
N	19,527	19,527	19,527	19,527	19,527
Adj-R^2	0.080	0.099	0.124	0.118	0.202

Notes: The values between parentheses are t-statistics. *** represents significance levels of 1%.

Column (1) and (2) report the regression analysis results for model (11). Column (1) explores the moderating role of firm size in the relationship between regional digitalization and enterprise exploitative innovation, while the interaction terms between regional digitalization and firm size have insignificant effects on enterprise exploitative innovation. Column (2) explores the moderating role of firm size in the relationship between regional digitalization and enterprise exploratory innovation. The results show that the coefficients of Rdi, Size, and Rdi × Size (the interaction term between regional digitalization and firm size) are 0.438, 0.267, and 0.180, respectively. All three coefficients are significantly positive at the 1% level, indicating that firm size positively moderates the relationship between regional digitalization and enterprise exploratory innovation. The above results indicate that Hypothesis 4a has not been thoroughly verified. In other words, large-scale manufacturing enterprises can better use regional digitalization empowering effect to carry out exploratory innovation. However, regional digitalization has the same empowering effect on large, small, and medium-scale manufacturing enterprises in driving exploitative innovation. The possible reasons for this are that exploitative innovation is less technical and innovative than exploratory innovation, and large-scale enterprises' resources and technological advantages do not play an absolute advantage. It also indicates that enterprises are equal in using digital technology for technological upgrades and product updates.

Column (3) and (4) report the regression analysis results for model (12), examining the moderating role of firm size in the relationship between enterprise digitalization and enterprise ambidextrous innovation. The regression coefficient analysis indicates that firm size does not significantly affect the relationship between enterprise digitalization and exploitative innovation. However, it does have a positive moderating effect on the relationship between digitalization and exploratory innovation. These results indicate that Hypothesis 4b has not been thoroughly verified. The result also reveals that digitalization has a more significant enabling effect on exploratory innovation for large-scale manufacturing enterprises, while the enabling effect of digitalization on exploitation innovation does not vary significantly among large, small, and medium-scale manufacturing enterprises. This could be attributed to the fact that the magnitude of digitalization's empowering effect depends on the company's innovative tendency and subjective initiative. Compared to exploratory innovation, exploitative innovation has lower uncertainty. Manufacturing enterprises often pursue short-term economic benefits through more exploitative innovation regardless of the firm size. Therefore, there is no clear distinction between large-scale,

small and medium-scale enterprises in terms of using digital technology for exploitative innovation.

Column (5) reports the regression analysis results for model (13), which examines the moderating effect of firm size on the relationship between regional digitalization and enterprise digitalization. The results show that the coefficients of Rdi, Size, and Rdi × Siz are 0.498, 0.139, and 0.160, respectively, all significant at the 1% level. This indicates that firm size positively moderates the relationship between regional digitalization and manufacturing enterprise digitalization, and Hypothesis 4c is verified. In other words, under the same circumstances, larger-scale manufacturing enterprises are more likely to achieve the transformation from digitalization empowering to digitalization enabling.

4.3. Robustness Tests

The robustness of the model was tested in this study by substituting variables and reducing sample size and lagging period to test the model's stability and the hypotheses' reliability.

Firstly, it was tested by replacing the explained variable that was replaced with the number of patent applications in the current year to measure exploitative and exploratory innovation, and the results are shown in Table 9. The regression results are generally consistent with the previous research in this paper, suggesting that the empirical results are robust. Moreover, an empirical analysis is conducted by sequentially substituting explanatory variables. On the one hand, the digitalization level of each province was measured using principal component analysis without considering the time factor instead of the original regional digitalization level variable. On the other hand, referring to a previous study [69], digital transformation word-frequency statistics were conducted in two dimensions: underlying technology use and technology practice application. And the natural logarithm of the total number of these word frequencies was taken as the new variable to measure enterprise digitalization for regression tests. Furthermore, the natural logarithm of the number of employees was used to measure the firm size and verify the robustness of the moderating results.

Table 9. The results of robustness testing.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Variable	**Exploi**	**Explor**	**Exploi**	**Explor**	**EDI**	**Exploi**	**Explor**	**Exploi**	**Explor**	**EDI**
Rdi	0.351 ***	0.347 ***			0.4964 ***	0.350 ***	0.348 ***			0.498 ***
	(4.296)	(4.860)			(8.4357)	(4.293)	(4.880)			(8.466)
Edi			0.296 ***	0.204 ***				0.295 ***	0.207 ***	
			(30.505)	(23.896)				(30.430)	(24.171)	
Size	0.271 ***	0.318 ***	0.230 ***	0.289 ***	0.1382 ***	0.271 ***	0.318 ***	0.231 ***	0.285 ***	0.139 ***
	(24.085)	(32.258)	(20.754)	(29.549)	(17.0118)	(24.069)	(32.332)	(20.697)	(28.998)	(17.115)
Rdi×Size						−0.025	0.144 ***			0.160 ***
						(−0.528)	(3.488)			(4.711)
Edi×Size								−0.002	0.034 ***	
								(−0.303)	(5.019)	
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	−2.866 ***	−5.448 ***	−2.636 ***	−5.177 ***	−0.0330	3.171 ***	1.604 ***	3.224 ***	1.749 ***	3.111 ***
	(−5.100)	(−11.098)	(−4.859)	(−10.825)	(−0.0815)	(6.236)	(3.611)	(6.544)	(4.027)	(8.487)
Year_FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	19,527	19,527	19,527	19,527	19,527	19,527	19,527	19,527	19,527	19,527
Adj-R^2	0.082	0.093	0.123	0.118	0.202	0.082	0.094	0.123	0.119	0.202

Notes: The values between parentheses are t-statistics. *** represents significance levels of 1%.

Secondly, since China's first official initiative to promote the construction of "Digital China" in 2015, provinces have increasingly focused on developing digital technology. In

addition, China strongly advocated the "Internet+" initiative in 2015, and more and more enterprises began to pay more attention to the digital transformation of enterprises and use digital technology for innovation development. Therefore, this paper uses 2016 as the starting year for sample data and conducts robustness tests by reducing the sample size.

Finally, considering that enterprise innovation activities need time cycles and innovation output may have certain lags, this paper treats the explained variables with one and two lag periods. In the regression, explanatory variables are both t periods, and explanatory and control variables are $t-1$ and $t-2$ periods. The regression results of the above models are generally consistent with the previous research in this paper, indicating that the research conclusions are robust. Because of the length of this paper, other robustness test results are not presented.

5. Conclusions and Implications

5.1. Research Conclusions

The Chinese A-share listed manufacturing companies from 2011 to 2021 were taken as the research sample in this study to explore the impact of digitalization on manufacturing ambidextrous innovation in a multi-dimensional. The conclusions of this study are as follows:

First, regional digitalization has a significant positive impact on exploitative and exploratory innovation in manufacturing enterprises, and digitalization has an empowering effect on the promotion process. Compared with network infrastructure construction, digital technology development, and digital technology application, regional digital talent reserve significantly impacts ambidextrous innovation in manufacturing enterprises. This means that the region's digital development will optimize the climate for social and technological innovation and increase the motivation of enterprises to implement innovation [13,14]. Furthermore, from the empirical results of this study, we can see that the positive effect of network infrastructure construction on both exploitative and explorative innovation of manufacturing firms is lower than that of digital talent reserve but far greater than that of digital technology development and application. This suggests that digital talent reserve and network infrastructure construction should be good starting points if a country intends to implement new digital and innovation public policies.

Second, manufacturing enterprise digitalization can effectively boost exploitative and exploratory innovation, and digitalization has an enabling effect on the facilitating processes. This shows that it is becoming increasingly crucial for manufacturing enterprises to inspire enterprise innovation through digital transformation [20]. We also find that regional digitalization can enhance the level of digitalization of manufacturing enterprises to promote enterprise ambidextrous innovation. Digitalization realizes the transformation from empowering to enabling, showing a path mechanism of regional digitalization–enterprise digitalization–enterprise ambidextrous innovation. Compared with network infrastructure construction, digital technology development, and digital technology application, regional digital talent reserve significantly facilitates the transformation. From this perspective, as the degree of digitalization continues to increase, the enterprise innovation model will evolve from empowering to enabling [38]. Digital talent is a core element in enterprises' digital transformation and innovative development [48]. Therefore, enterprises can accelerate their level of digitization and innovation by relying on regional digitalization development and focusing on applying digital talent.

Third, firm size has a positive moderating effect on the relationship between regional digitalization and exploratory innovation in manufacturing enterprises, as well as the relationship between enterprise digitalization and exploratory innovation in manufacturing enterprises. Additionally, firm size has a positive moderating effect on the relationship between regional digitalization and enterprise digitalization. This finding supports the idea that there is a digital divide in the enterprise. Larger firms are more likely to have better access to digital resources [19]. This means that in the digital age, large firms have more opportunities and strength to innovate and develop.

5.2. Theoretic Contributions and Practical Implications

This paper explores digitalization empowering and enabling effects on innovation in manufacturing enterprises, with some theoretical implications for digitalization and enterprise innovation. Firstly, while there is a consensus on the role of digitalization in promoting enterprise innovation, the exploration of the multilevel impact of digitalization is still in its early stages. This paper explores the multilevel impact of digitalization on enterprise ambidextrous innovation from regional and enterprise digitalization perspectives. It provides new insights for scholars to explore digital innovation more deeply. Secondly, digitalization empowering and enabling effects on innovation have attracted scholars' attention [38,40]. However, most research on digitalization empowering and enabling is theoretical. This paper employs empirical methods to explore the empowering and enabling mechanisms of digitalization on the ambidextrous innovation of manufacturing enterprises. It is valuable in deepening our understanding of digitalization empowering and enabling and clarifying digitalization's impact on different innovation activities. Thirdly, there is an increasing amount of research on digitization and innovation, yet due to varying research perspectives, the utilized innovation theories are scattered, resulting in a lack of proprietary theories on digital innovation. This paper integrates the theories of digitalization empowering and digital technology availability to explore the effect of regional digitalization empowering and enterprise digitalization enabling. The analysis process in this study involves innovation diffusion theory, dynamic capability theory, and environmental adaptability theory, which contribute to developing proprietary theories on digital innovation and a unified research system.

Our results offer some significant managerial implications for governments and firms in emerging economies. First, government should vigorously promote regional digitalization and create a favorable environment for innovation. On one hand, governments and relevant departments should seize digital opportunities and promote innovation and development in the digital industry and manufacturing sector through policies such as tax incentives and fiscal subsidies. On the other hand, in the continuous convergence of digital technology and innovation development, different regions can implement public policies that align with their development situations. For example, economically developed countries and regions can focus on cultivating digital talent, strengthening network infrastructure construction, and continuously enhancing digital technology development and application. Economically underdeveloped countries and regions can prioritize optimizing network infrastructure construction and implementing policies to attract digital talent.

Second, firms should continue to promote digital transformation and stimulate innovation momentum. On the one hand, manufacturing firms should cultivate a digital mindset and vigorously promote the practice of digitalization. Enterprises should also recognize the arduous and prolonged nature of digital transformation. As such, they need to increase the recruitment and training of digital talent to strengthen the confidence and effectiveness of digital transformation. Moreover, enterprises should carefully align digital transformation with their growth agenda to achieve tremendous momentum for innovation. On the other hand, manufacturing firms should enhance their use of digital technologies to improve the quality and efficiency of both exploitative and exploratory innovation. For instance, large-scale manufacturing enterprises could leverage their scale advantages to strengthen the exploration and application of data technology and digital elements. And they will achieve more exploratory innovation by tapping into digitalization potential. Small and medium-scale manufacturing enterprises could leverage digitalization to enhance their exploitative innovation capability and consistently narrow the technological gap with advanced enterprises.

5.3. Limitations and Prospects

There are some limitations in this study that should be considered in future research. First, this study only takes the China manufacturing industry as the research object to explore the promotion effect of regional digitalization and enterprise digitalization on

enterprise ambidextrous innovation, so there may be a concern that the results are industry-specific and country-specific. In addition, the impact of digitization on enterprise innovation may change over time. Future research could generalize the findings using other data or multiple data sources to enhance validity. Second, this study uses text analysis to measure the overall situation of enterprise digitalization but fails to describe the development process of enterprise digitalization accurately. Future research could explore the interaction between digitalization empowering and enabling by distinguishing the digital transformation processes. Third, this study uses patents to measure exploitative and exploratory innovation. Future research could consider alternative methods to measure exploitative and exploratory innovation and comprehensively understand the relationship between digitalization and these two types of innovation.

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