Research Article

Impact of Digital Transformation on Accelerating Enterprise Innovation—Evidence from the Data of Chinese Listed Companies

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Under the background of the rapid development of digital economy, this paper empirically analyzes the impact of digital transformation on enterprise innovation and selects the panel data of China's Shanghai and Shenzhen A-share listed companies from 2013 to 2021 as the research objective is to study the impact of digital transformation on enterprise innovation from theoretical and empirical perspectives. First, we find that digital transformation accelerates enterprise innovation, a conclusion that has been validated through robustness testing. Second, digital transformation impacts enterprise innovation by enhancing productivity and information transparency. Third, financing constraints and financial redundancy play distinct regulatory roles in the process. Fourth, heterogeneity analysis finds that the role of digital transformation in promoting enterprise innovation has different effects in state-owned and non-state-owned enterprises, high-tech and non-high-tech enterprises, and enterprises with different life cycles. Finally, the functional analysis suggests that further investigation is needed to determine whether digital transformation can significantly promote the sustainable development of enterprises through innovation while also recognizing that this function may have a lag effect. Overall, this study contributes to a deeper understanding of digital transformation and innovation-driven practices and encourages more significant integration of the real and digital economies.

1. Introduction

With the vigorous development of emerging technologies, digital transformation has gradually become the focus of gaining competitive advantage in today's fast-paced business environment because digital transformation can realize the integration and collaborative innovation of global supply chains and open borderless business opportunities. This paper aims at studying the impact of the digital transformation of Chinese A-share listed companies on corporate innovation. In China, a digital economy is a new form of agricultural and industrial economy. With high innovation, strong permeability, and comprehensive coverage, the digital economy is a unique economic growth point and a fulcrum for transforming and upgrading traditional industries [1]. The digital economy has good development momentum and the overall scale has expanded. The proportion of the digital economy in GDP has increased from

27% to 38.6%, thus becoming a vital driving force for stable economic growth. Meanwhile, enhanced digital technology and digitalization can increase people's happiness [2] materially and spiritually and have greatly affected people's overall lives. Amidst the backdrop of the comprehensive digitization of society and the economy, the driving force of digital transformation has become increasingly prominent and an essential means of promoting industrial upgrades and high-quality development. Over the past decade, the widespread use of digital technologies has expanded further and has become an intrinsic dimension of a country's drive for a more inclusive, competitive, and sustainable economy and society [3]. Digital transformation results in coordinating the limited resources of enterprises through the use of digital technology to improve the efficiency of resource allocation and operation [4]; it can also change the strategic behavior of companies [5] to ensure that the process reduces costs, increases efficiency, and assists

innovation activities. Therefore, it is important to create a suitable, efficient, and stable financial environment and guide capital elements to combine with entity micro-enterprises and support microenterprise innovation to achieve high-quality economic development [6]. Therefore, studying the relationship between digital transformation and enterprise innovation for stable economic growth is significant. The state also encourages enterprises to carry out digital transformation. The efforts of digitization can send valuable signals to the institutions responsible for subsidy distribution [7].

The existing research on digital transformation mainly focuses on economic efficiency [8], environmental performance [9], and the improvement of total factor productivity [10]. During the initial stages of the digitalization era, some scholars [11, 12] employed the scale to develop digital maturity evaluation models, thus digital maturity was recognized as the standard of digital transformation by the academic community and the industry [13]. Some scholars [14, 15] have conducted empirical research using survey questionnaires, such as Choi [16], who found that digital transformation promotes knowledge sharing in enterprises, thus stimulating innovation. In this study, Python is used to extract a data pool comprising the textual content of annual reports from listed companies. It is then used to conduct searches, matches, and word frequency counts based on specific keywords while quantifying the degree of digital transformation through logarithmic calculations. This approach helps mitigate potential subjective biases and other issues associated with questionnaires or alternative methods. On the one hand, this study employs the intermediary utility model to identify and examine the pathway of "digital transformation-productivity (information transparency)-enterprise innovation." By doing so, we elucidated the previously unexplored aspects of how digital transformation impacts enterprise innovation. This enriches the existing research on factors influencing enterprise innovation and aligns with the requirements of high-quality innovation-driven development in the era of the digital economy. On the other hand, given the substantial financial requirements for enterprises' digital transformation, when external financing constraints exert pressure on enterprises, they are compelled to rely more on internal funds to fulfill their funding needs. Consequently, financial redundancy can augment the reserve of internal funds. Therefore, we examine the moderating effect of digital transformation on enterprise innovation from the perspectives of financing constraints and financial redundancy. In recent years, the Chinese government has proposed and vigorously promoted a digital-driven development strategy. Theoretically, this microlevel understanding can help enterprises adapt to the digital business environment more quickly; from a practical point of view, these findings can help companies adjust their strategies to accelerate innovation. In summary, through what channel does digital transformation affect enterprise innovation? Does the demand for funds play a regulatory role in it? There is very little literature to study this problem, and our paper aims to study this aspect.

The main contributions of this paper are as follows. First, this paper shows that digital transformation can promote innovation among Chinese enterprises, and on this basis, it tests the path of digital transformation, which progresses through productivity (information transparency) to enterprise innovation. In contrast to other scholars' research paths [17–19], this paper expands the cognition of the mechanism of digital transformation that empowers the enterprise innovation process. Second, from the perspective of external financing conditions and the company's own redundant funds, this paper presents an analysis of the moderating effect of the two situations in the relationship between digital transformation and enterprise innovation. We find that the former has a reverse adjustment effect, while the latter has no obvious effect. Third, different from previous scholars' research on the classification criteria of region [20] and enterprise scale [21], we classify enterprises according to the three classification criteria of property rights, high-tech level, and enterprise life cycle and study the innovation effect of digital transformation on different types of enterprises. Subsequently, we also found that digital transformation accelerates enterprise innovation, which promotes the sustainable development of enterprises. This work not only enriches the literature on digital transformation in enterprise innovation but also provides valuable insights for enterprises to enhance the practice of innovation activities.

The rest of this article is organized as follows: In the second section, the literature is reviewed and hypotheses are presented on this basis; the third part introduces the digital sources; in the fourth and fifth parts, the impact mechanism of digital transformation on enterprise innovation is examined; the sixth part presents the expansion analysis; and the seventh part presents the conclusion and significance of the findings.

2. Theory and Hypotheses

2.1. Digital Transformation Can Promote Enterprise Innovation. Scholars have studied the impact of digital transformation on health [22, 23], employment [24, 25], and other pertinent social issues [26–28]. Adopting a business perspective that acknowledges the potential of digital transformation to transcend geographical and industrial boundaries, this study investigates its influence on enterprise innovation and subsequent business prosperity. Building upon this foundation, the role of digital transformation in fostering enterprise innovation is examined. According to the theory of technology communication, digitization provides a more effective channel for disseminating technology communication. The widespread availability and utilization of the Internet and social media platforms have facilitated the rapid dissemination and adoption of novel technologies, thereby promoting innovation at an accelerated pace. It is crucial to apply this theory in practical advancement, as the profound implementation of cutting-edge information technologies such as big data, artificial intelligence, and blockchain has exerted a significant impact on innovation endeavors, instigating transformations in the conventional

mechanism of factor flow. By transcending barriers among innovation stakeholders, the full potential of talent, capital, information, technology, and other elements is unleashed [29]. It has become a new paradigm of scientific and technological innovation to realize collaborative and integrated innovation of deep cooperation [30].

Existing scholars have found that digital transformation does not significantly impact innovation performance [31]. However, some scholars have mentioned that digital transformation subverts the traditional innovation model [32]. Although scholars have different views on this, we concede that digital transformation is a fundamental change brought about by the integration, diffusion, and influence of the new generation of digital technology [33]. According to the theory of innovation ecosystem, digitization frosts a global innovation ecosystem that facilitates enhanced collaboration and interaction between innovators, investors, users, and governments. This collaborative environment promotes resource sharing mitigation, and accumulation of innovative ideas, thereby fostering prosperity in innovation. Simultaneously, enterprise innovation has gained increasing attention in business research [34]. The innovative development and application of the new generation of digital information technology represented by "artificial intelligence," "blockchain," "cloud computing," and "big data" provide a platform for accelerating enterprise innovation [35]. Enterprises will bring about changes in the process in the development of new platforms. According to the theoretical analysis of process reengineering by Hammer and Champy scholars, the fundamental idea is to incorporate process reengineering into the daily production and business operations of enterprises. Digital transformation introduces novel processes and mechanisms, encompassing comprehensive design considerations, maximizes the integration of technical functions and management functions, transcending traditional functional organization boundaries and establishing a new process-oriented organizational structure. This ability to restructure, deploy, and leverage the core capabilities of the organization to achieve the ability to keep pace with the evolving times is essential for the innovation process [36], and it is also advocated by dynamic capability theory. This ability enhances cost-effectiveness, quality, service, and operational speed within enterprises, which are critical factors for undertaking novel business processes and thereby expediting innovation and development [37]. However, a good platform can attract more talent. Digital technology makes it easier for enterprises to recruit high-skilled talent to meet their needs. Technical personnel are better able to accept, decode, and apply new knowledge and improve innovation [38]. With the acceleration of the digital transformation of enterprises, this field has also become a research hotspot.

Based on the above analysis, this paper proposes the first hypothesis:

H1: Enterprise digital transformation can accelerate enterprise innovation.

2.2. The Mediating Effect of Productivity in Digital Transformation Accelerating Enterprise Innovation.

With the rapid development of digitalization based on modern information network technology, enterprises use digital transformation to bring fruition transformation and upgrading. In this context, the continuous improvement of enterprise productivity has gradually emerged as the primary feature and critical driving force of high-quality economic growth. Endogenous technological progress is the main driving force for sustained economic growth, which is also the content advocated by endogenous growth theory. The theory holds that in the process of digital transformation, the accumulation and dissemination of vast information and knowledge of enterprises play a vital role in the economic growth brought by a technological progress [39]. Digitization can break through the limitation of time and space and promote the massive storage of information around the world and carry out high-speed transmission and integration processing. Every economy can apply the existing information, use digital technology to delve, process, and analyze the information, and further realize the improvement of productivity. At the same time, the theory has also been proved in the research of scholars. Existing research shows that human capital [40], accumulation of industrial science and technology [41], and external direct investment [42] are all critical factors that affect enterprise productivity. Digital transformation can encourage manufacturing enterprises to build a production mode of ubiquitous perception, intelligent decision-making, agile response, global coordination, and dynamic optimization and use the new generation of information technology to deeply integrate with production and business activities [43], reconstruct enterprise productivity and production relations, accelerate the transformation of production mode and enterprise form, and realize enterprise innovation. Its role is mainly reflected in the following two aspects.

First, enterprises use big data technology for data mining, sorting, and analysis and use artificial intelligence technology to obtain feedback information generated in the process of production and operation in time to optimize the production process [44]. Digital technology has also reshaped the interaction mode between enterprises and consumers. Digital technology enables consumers to participate in the production process of products, facilitating a closer relationship with producers. This is consistent with the claims of resource dependence theory, namely, that if the enterprise is an open system, it is impossible for an enterprise to have all the resources, and enterprise survival and development are inseparable from the exchange of resources among multistakeholder groups, such as customers, suppliers, or competitors. From the perspective of consumers, according to the characteristics of their demand, enterprises design new products that are more in line with the market trend and closer to the personalized needs of consumers [45]. Through the digitization of R&D and marketing links, enterprises focus on the use of big data, AI, and other technologies to accurately locate the consumption needs of each customer, adjust product innovation strategies promptly according to the differences and dynamic changes

in user demand preferences, identify market opportunities for new products and services, and ultimately improve enterprise productivity and innovation efficiency [46].

Second, digital technologies such as the Internet, big data, quantum computing, and artificial intelligence are the material technologies that support the operation of new models and new formats related to the digital economy [47]. They have a wide range of connectivity, interaction, understanding, and integration capabilities. They can simplify the process of data information collection, transmission, and analysis, realize the visualization of enterprise management and the intelligence of business decision-making, and effectively reduce enterprise information search, supervision and transaction costs [48]. Therefore, digital transformation reduces costs by improving technology. Unlike cutting corners and lowering costs, cost reduction and empowerment can drive enterprises to use various technologies [10], change the cost structure of traditional products, improve enterprise productivity, and bring innovation to enterprises.

In summary, this paper proposes the second hypothesis:

> H2: The impact of digital transformation on enterprise innovation can be achieved by improving enterprise productivity.

2.3. The Mediating Effect of Information Transparency in Digital Transformation Accelerating Enterprise Innovation. The research of H2 shows that data-driven decision-making brought by digital transformation helps to optimize the allocation of production factors, and this effective resource allocation further promotes the implementation of enterprise innovation. Through open and transparent information disclosure, enterprises can enhance market trust, attract investors and partners, and also obtain better resource allocation and support. Therefore, enterprises can also enhance innovation by improving information transparency in the process of digital transformation. The improvement of information transparency can reduce the difference in the degree of information understanding between people in market economic activities. This information asymmetry has become the basic theory in the development of the market economy, and this phenomenon is everywhere [49]. According to the theory of digital economy, digital economy is a new economic system that can digitize personal information, enterprise information, and national information. Through digital transformation, enterprises can more effectively evaluate, absorb, and utilize new information to obtain key resources [50]. As the transformation deepens, it is easier to attract the attention of analysts and media reports in the market, thereby increasing corporate information disclosure [34]. External stakeholders can make full use of this information to make decisions to broaden the space of information transparency between the two sides and correct the problems caused by information asymmetry to a certain extent, which makes various innovation activities of enterprises possible.

On the one hand, improving corporate information transparency can prevent identified earnings manipulation and significantly improve corporate governance. High transparency of earnings information can pass on the company's solvency, profitability, and future operating conditions to the capital market, which helps investors monitor the company. Investors can more accurately assess appropriate risks and expected returns and more rationally allocate their funds [51]. In addition, the new generation of technology can break through the limitations of time and space, enable the explosive dissemination of information, and thereby reduce the transaction costs caused by information asymmetry [52]. Therefore, investors can fully understand the enterprise, effectively reduce the level of information asymmetry between enterprises and investors, and enhance investors' willingness to invest [53].

On the other hand, higher information transparency can show the details and efforts of managers' decision-making to shareholders and dispel the concerns and exclusions of management on innovation. As an "invisible incentive contract," information transparency can stimulate managers and venture capital institutions to carry out innovative activities. The intermediary mechanism of digital transformation to improve enterprise information transparency is consistent with the content of knowledge economy theory. This theory holds that digitization provides a wide and direct way to obtain information, so that innovators can acquire and share knowledge faster. The digital development of knowledge has accelerated the speed and quality of innovation by facilitating cross-disciplinary collaboration and enabling new collective intelligence [54]. Therefore, this paper puts forward the third hypothesis:

> H3: Digital transformation affects enterprise innovation by improving enterprise information transparency.

In summary, to provide a visualize representation of how digital transformation affects enterprise innovation, this paper draws a research mechanism framework (Figure 1).

3. Research Design

3.1. Data and Sample. This paper selects China's Shanghai and Shenzhen A-share listed companies from 2013 to 2021 as the initial research samples and carries out the following processing. First, to ensure the integrity and comparability of the data, samples with missing and abnormal data are eliminated. Second, considering the particularity of the asset-liability ratio of the financial insurance industry, the sample of the financial insurance industry is eliminated. Third, the samples in the ST and delisting state during the sample period are eliminated to ensure that the enterprise is in a state of sustainable operation, excluding companies with missing variables during the sample period. Enterprise innovation is measured by the number of patents applied for by enterprises in the CNRDS database. Other data are pulled from the CSMAR database. In this paper, all continuous variables were tailed up and down by 2%, and statistical analysis was performed using Stata 17.0 software.

3.2. Measurement

3.2.1. Dependent Variable: Innovation. This paper uses patent application indicators to measure enterprise innovation. Compared with R&D investment, patent data
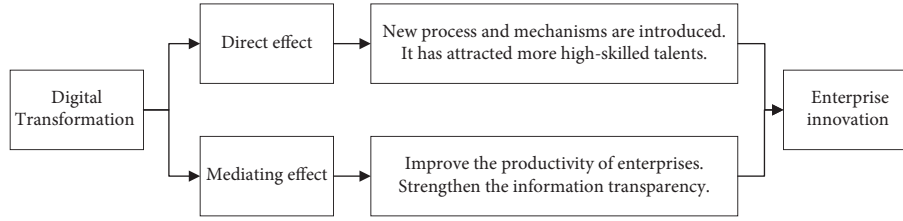
Figure 1: Mechanism circuit diagram.

more intuitively describe the innovation level of enterprises [55], which can directly reflect the utilization efficiency of input resources and better reflect the ability of enterprise innovation. Considering that the number of annual patent applications of some enterprises is 0 and the distribution of the number of patent applications has an obvious thick tail phenomenon, the number of patent applications +1 is logarithmically processed.

3.2.2. Independent Variable: Digital Transformation (Digital). Because digital transformation is related to the top-level strategic decision-making of the current and future development of the enterprise, such information is more likely to appear in the abstracts and guidelines of the annual report. Therefore, this paper adopts text mining technology to extract the keywords of digital transformation related to the annual report text of listed companies [56], search, match, and count word frequency according to the feature words, and then classify the word frequency of the key technical direction and form the final sum word frequency to construct the index system of enterprise digital transformation. Due to the "right deviation" characteristics of such data [57], the number of patents applied for logarithmic processing, that is, LN (the number of patents +1), is used to measure enterprises' degree of digital transformation.

3.2.3. Control Variables. The control variables used in this paper are mainly enterprise structure, operating conditions, corporate governance and other indicators, which may be important factors affecting enterprise innovation [18]. If these variables are not considered, the estimation results may be biased. The scale of the enterprise is selected as the control variable. According to Schumpeter's innovation hypothesis, the larger the enterprise is, the more inclined it is to innovate [58], while large enterprises may have more fixed asset capital density (fixed) to measure the ability of enterprises; the return on equity (ROE) can reflect the income level of shareholders' equity; and the market value of the enterprise can be explained by growth (TobinQ). Regarding board governance structure, the number of directors (board) is selected for measurement. In addition, according to life cycle theory, a company's establishment period (FirmAge) will also affect enterprise innovation. The control variables of these six variables are shown in Table 1.

3.3. Model. First, the Hausman test determines whether the sample uses a fixed effect or a random effect model. The calculated result is $P \leq 0.001$, indicating that our data are more

suitable for a fixed effect model. Therefore, we construct the following Model (1) to verify the establishment of H1.

$$\text{Innovation}_{i,t} = \partial_0 + \partial_1 \text{Digital}_{i,t} + \sum \text{Controls}_{i,t} + \sum \text{Year}_{i,t} + \sum \text{Individual}_{i,t} + \varepsilon_{i,t}. \tag{1}$$

In Model (1), i represents the enterprise, t represents the Year, and $\partial 0$ is the constant term. To prevent our results from being adversely affected by individual industry characteristics and time factors, we control the dummy variable, where Year is the time dummy variable. Individual is the individual dummy variable, and ε is the residual term.

4. Empirical Results and Analysis

4.1. Descriptive Statistical Analysis of Variables. The descriptive statistics of the main variables used in this study are listed in Table 2. The maximum value of enterprise innovation is 9.8615, and the minimum is 0.0000, indicating that the number of patents applied for differs by enterprise. There are apparent differences between samples, which means that most Chinese enterprises are in the stage of low-quality innovation. The maximum value of digital transformation is 6.1070, the minimum value is 0.0000, and the average value is 1.0986. Most Chinese enterprises are in the stage of industrialization, the level of digital transformation is low, and the degree of digital transformation of different enterprises is quite different, which reflects the reality that the investment in the digital transformation of listed companies in China is uneven. Regarding control variables, there are diverse degrees of differences in Size, Fixed, ROE, TobinQ, Board, and FirmAge.

4.2. Correlation Analysis. In this paper, the main variables were the Pearson correlation test; the results are shown in Table 3. Digital transformation is significantly positively correlated with enterprise innovation, which preliminarily verifies H1 and is consistent with the existing research conclusions. In addition, the correlation coefficients between other variables are relatively small. According to the collinearity test results, the variance inflation factor (VIF) value is less than 2, which is less than the critical empirical value of 10 [59]. Multicollinearity was not a severe threat to the results, and Model (1) is more appropriate.

4.3. Regression Results of Digital and Innovation. The data in Column (1) of Table 4 are obtained through univariate fixed effect regression based on model (1). The results show that

TABLE 1: Meaning of the main variables.

Variable name	Meaning
Innovation	Patent application times of enterprises
Digital	Digital transformation index constructed by Python text mining technology
Size	Natural logarithm of total annual assets
Fixed	The ratio of fixed assets to total assets
ROE	The ratio of net profit to the average balance of shareholders' equity
TobinQ	The ratio of enterprise market value to replacement cost
Board	The number of board members takes the natural logarithm
FirmAge	LN (year-year of establishment +1)

TABLE 2: Descriptive statistical analysis of variables.

Variable name	N	Mean	SD	Min	Median	Max
Innovation	9522	2.8483	1.7320	0.0000	3.0910	5.6802
Digital	9522	1.3068	1.2930	0.0000	1.0986	3.9890
Size	9522	22.2928	1.0570	20.5751	22.1929	24.4902
Fixed	9522	0.2158	0.1450	0.0136	0.1923	0.5230
ROE	9522	0.0664	0.0830	−0.1408	0.0646	0.2220
TobinQ	9522	1.9474	0.9970	0.9171	1.6093	4.5998
Board	9522	2.1258	0.1620	1.7918	2.1972	2.3979
FirmAge	9522	2.9418	0.2910	2.3026	2.9957	3.3673

TABLE 3: Correlation coefficient.

	Innovation	Digital	Size	Fixed	ROE	TobinQ	Board	FirmAge
Innovation	1							
Digital	0.1890***	1						
Size	0.3090***	0.1410***	1					
Fixed	0.0030	−0.3060***	−0.0280***	1				
ROE	0.1310***	0.0680***	0.1940***	−0.1140***	1			
TobinQ	−0.0970***	0.0360***	−0.451***	−0.0500***	0.0990***	1		
Board	0.0480***	−0.0210**	0.1900***	0.0570***	0.0590***	−0.1150***	1	
FirmAge	−0.0480***	0.0150	0.1810***	−0.0160	−0.0330***	−0.0980***	0.0590***	1

Note. *, **, and *** indicate statistical significance levels of 10%, 5%, and 1%, respectively, based on coefficient significance tests. The following tables convey the same information, with t-values enclosed in parentheses. The t-value is calculated as the ratio of the regression coefficient to its standard error.

digital transformation significantly impacts enterprise innovation ($\partial1 = 0.0879$, $P < 0.01$). To ensure the accuracy of the research results, six control variables were added to Column (2) for fixed effect regression. The results show that the coefficient of digital transformation to enterprise innovation is still positive and significant ($\partial1 = 0.0446$, $P < 0.01$). The R^2 of the model increases, indicating that for every 1-point increase in digital transformation, the innovation of enterprises increases by 0.0446 percentage points. Therefore, H1 is supported. This is consistent with the research of Liu et al. Digital transformation can promote enterprise innovation by reducing transaction costs and enhancing consumer experience [18]. These research studies expounded the role of digital transformation in promoting enterprise innovation from the perspectives of innovation input and innovation output. However, the research in this paper is different from that in Usai et al. [60], who found that the impact of digital technologies on innovation performance is relatively small. The reason for this difference is, on the one hand, because Usai uses Eurostat data to study the digital transformation of European companies. On the other hand, the research

methods employed are different. Usai mainly used principal component analysis and multivariate analysis of variance. In addition, the research in this paper also differs from the conclusions of the study by Xing et al. [61]. These authors collected 287 questionnaires and used SPSS software to determine that enterprises cannot improve their innovation performance through digital transformation. Our study collects A-share data and uses empirical research methods to analyze problem. A reliable conclusion is obtained, which is also reflected in the real operating activities of the company. For example, Linglong Tire Company has conducted digital transformation from the aspects of integrated information systems and supply chain integration. The enterprise optimized the supply chain process, reduced the cost of R&D, manufacturing and sales, and improved its innovation performance to a certain extent. In addition, the FAW Group constantly adjusts its strategies under the guidance of an overall digital transformation strategy. The company has undergone three stages of platform digitization, namely, local end digitization, platform end digitization and ecosystem digitization, resulting in an increase in innovation output.

Table 4: Benchmark regression results.

	(1) Innovation	(2) Innovation
Digital	0.1393*** (9.8112)	0.0960*** (6.9364)
Size		0.5928*** (25.3791)
Fixed		0.8917*** (6.7045)
ROE		0.4869*** (3.1774)
TobinQ		0.0094 (0.5695)
Board		−0.1457 (−1.3836)
FirmAge		0.5037*** (4.1174)
Year	YES	YES
Individual	YES	YES
_cons	0.1393*** (9.8112)	−11.9079*** (−17.9473)
N	9522	9522
Adj. R^2	0.689	0.715

4.4. Robustness Test

4.4.1. Replacing the Dependent Variable. The greater the number of R&D personnel, the more human resources the enterprise has invested in innovative activities [62]. In this paper, the ratio of the number of R&D personnel to the total number of employees is used to remeasure enterprise innovation. The dependent variable is replaced by fixed effect regression. Table 5 Column (1) shows that the coefficient is positive ($\partial 1 = 0.4544$, $P < 0.01$). It is still significant, which supports H1.

4.4.2. Replacing the Independent Variable. Redefining Digital. Set independent variables to determine whether the enterprise is undergoing digital transformation [57]. If there is no digital word frequency in the enterprise's annual report, it indicates that the digital transformation is not carried out in the year, and the value is 0; otherwise, the value is 1. The robustness result Column (2) shows that the coefficient of digital transformation is positive and significant ($\partial 1 = 0.0690$, $P < 0.1$), indicating that H1 is significantly supported.

4.4.3. Tobit Model Test. Because the number of patents of listed companies has many zero values, there are characteristics of truncated data. This paper uses the Tobit model [63] to further study the impact of digital transformation on enterprise innovation. Column (3) of Table 5 shows that the coefficient of digital transformation is still significantly positive ($\partial 1 = 61.1281$, $P < 0.01$), which also proves the robustness of the previous results.

4.4.4. Endogeneity Problem Handling: Lag Period Regression. This paper aims to discuss the impact of digital transformation on enterprise innovation. Nevertheless, it may also be that enterprises with vital innovation are more inclined to carry out digital transformation. This relationship may lead to endogenous problems of causal two-way interaction. To solve these problems, this study lags behind enterprise innovation data for regression [18]. The lag data are used because the data collected by the annual report disclosure of digital transformation and enterprise innovation may be related to past information. Column (4) of Table 5 analyzes the digital transformation data one period later. The influence coefficient is 0.0276, which is still positive. In summary, digital transformation can promote enterprise innovation over a long period, thus stimulating the rise of enterprise innovation to a greater extent. This finding supports core H1 of this study.

5. Mechanism Analysis

In the hypothesis, digital transformation is claimed to promote enterprise innovation by improving total factor productivity and improving information transparency. To verify whether the hypothesis is supported, we construct new models for model (2) and model (3) to test the two mediating effects. First, to measure the productivity of enterprises, the literature generally uses total factor productivity (TFP) [64]. To calculate the residuals, the ordinary least squares (OLS) method is used for linear estimation. This is a method to assess the TFP of enterprises under the assumption that economic activities follow a specific production function [65]. In the calculation, the four variables of output, capital input, labor input, and intermediate input are logged for OLS regression to measure the productivity of enterprises. The four variables are presented in Table 6. In addition, the number of analysts tracking (analyst) is used to measure the transparency of enterprise information. The larger the index value is, the higher the transparency of enterprise information is.

$$\text{TFP}(\text{Analyst})_{i,t} = \beta_0 + \beta_1 \text{Digital}_{i,t} + \sum \text{Controls}_{i,t} + \sum \text{Year}_{i,t} + \sum \text{Individual}_{i,t} + \varepsilon_{i,t}, \tag{2}$$

$$\text{Innovation}_{i,t} = \theta_0 + \theta_1 \text{Digital}_{i,t} + \theta_2 \text{TFP}(\text{Analyst})_{i,t} + \sum \text{Controls}_{i,t} + \sum \text{Year}_{i,t} + \sum \text{Individual}_{i,t} + \varepsilon_{i,t}. \tag{3}$$

Second, according to the above regression results, the coefficient ∂_1 in Mode (1) is significant, which indicates that the main regression effect is substantial and can be tested next. Then, the coefficients β_1 in Model (2) and θ_2 in Model

TABLE 5: Robustness test results.

	(1) Innovation	(2) Innovation	(3) Tobit	(4) L.innovation
Digital	0.4544*** (4.0505)	0.0690*** (2.6150)	61.1281*** (12.5883)	0.0456*** (2.6302)
Size	0.8372*** (4.0674)	0.4804*** (19.8877)	151.7064*** (26.4135)	0.3739*** (10.6937)
Fixed	−3.7618*** (−3.3420)	0.0069 (0.0531)	84.2123** (1.9865)	0.1587 (0.8812)
ROE	−0.0294 (−0.2704)	0.0154 (1.0772)	130.9645*** (3.8026)	−0.0176 (−1.1483)
TobinQ	−0.0464 (−0.8109)	0.0116*** (3.8945)	5.6778*** (2.8614)	0.0117 (1.5162)
Board	0.7231 (1.0176)	0.0792 (0.8975)	−38.4191 (−1.1680)	0.0738 (0.7008)
FirmAge	6.7960*** (4.1985)	−0.0683 (−0.3408)	−100.6398*** (−5.0820)	−0.0360 (−0.1056)
Year	YES	YES	YES	YES
Individual	YES	YES	YES	YES
_cons	−28.3224*** (−4.3694)	−7.8610*** (−9.9183)	−3099.2200*** (−22.8188)	−5.6088*** (−4.4208)
N	8132	9511	9511	6971
R^2	0.754	0.800		0.822

TABLE 6: Total factor productivity index.

Variable name	Meaning
Output	Operating income of the year
Capital investment	Net fixed assets at year-end
Labor input	Number of employees
Intermediate input	Operating costs + sales costs + financial costs + management costs

(3) are tested. If both are significant, the indirect effect is significant. Third, we continue to test the coefficient θ_1 in Model (3). If θ_1 is not significant, it shows that the direct impact is not significant and that there is a full mediating effect; if θ_1 is significant, the direct effect is significant and needs further testing. Finally, if the symbol of $\beta_1 \times \theta_2$ is the same as that of θ_1, there is a partial mediating effect; otherwise, there is a masking effect [66].

5.1. Analysis of the Mediating Effect of Enterprise Productivity in Digital Transformation Accelerating Enterprise Innovation. According to the above test method of the mediating effect, Table 7 reveals that the coefficient ∂_1 in Model (1) is significantly positive at the level of 1%, its coefficient is 0.1001, the coefficient of Model (2) β_1 is 0.0323, the coefficient of Model (3) θ_2 is 0.0862, $\beta_1 \times \theta_2 = 0.0028$, $\theta_1 = 0.0324$, and the symbols of $\beta_1 \times \theta_2$ and θ_1 are the same, indicating that digital transformation affects enterprise innovation by improving enterprise productivity. H2 is verified. In contrast to previous studies, Zhou et al. found that digital transformation can help enterprises innovate by improving the quality of innovation and enhancing the ability to transform [17]. In addition, due to the different research perspectives, Ning et al. claims that absorptive capacity is a learning mechanism

TABLE 7: Test results of the mediating effect of enterprise productivity.

	TFP	Innovation
TFP		0.0862*** (2.7553)
Digital	0.0323*** (6.0595)	0.0324** (2.2218)
_cons	−6.9451*** (−22.5860)	−7.8038*** (−9.0051)
Controls	YES	YES
Year	YES	YES
Individual	YES	YES
N	8765	8765
Adj. R^2	0.938	0.799

that adapts to external knowledge. Through digital transformation, enterprises have fully leveraged internal and external knowledge to promote innovation [67]. In addition to the above path, digital transformation can also help enterprises improve the efficiency of resource utilization in the production process, thereby improving total factor productivity. When the total factor productivity of enterprises increases, they have more resources and capabilities to

invest in R&D and innovation activities, thus promoting enterprise innovation. For example, Mengniu Dairy, a leading consumer goods enterprise, has been accelerating the digitalization of its enterprises since 2018. It has actively been exploring the digital construction of raw materials, production processes, supply chain operations, customer service and other links, improved TFP, and stimulated product structure and business model innovation.

5.2. Analysis of the Mediating Effect of Information Transparency in Digital Transformation Accelerating Enterprise Innovation. Column (1) of Table 8 shows that the regression coefficient of digital transformation is positive ($\beta_1 = 0.0517$, $P < 0.01$); that is, enterprises transform the original data into standard information through digital transformation, release information dividends, and improve enterprise information transparency. The regression coefficient of information transparency in Column (2) is also positive ($\theta_2 = 0.0566$, $P < 0.01$); that is, with the improvement of information transparency, investors' understanding, and willingness to invest in enterprises are enhanced, thus promoting enterprise innovation. The regression coefficient of digital transformation is significantly positive; that is, digital transformation affects enterprise innovation by improving enterprise information transparency. Thus, H3 is verified. Digital transformation makes information acquisition and transmission more convenient and strengthens communication and information exchange between enterprises and customers, suppliers, and other stakeholders. The information transparency of enterprises has many effects. Jiaqi et al. found that in the process of marketization, the higher the level of information transparency is, the weaker the negative impact on family control and equity cost [68]. From the perspective of the innovation assessed in this study, when enterprises have high information transparency, they can better understand market demand, competition and new technology trends and provide more accurate guidance and direction for their innovation, which is consistent with the research conclusions of Aloini et al. Information and communication technology in digital transformation can provide enterprises with unprecedented tools to support their open innovation process [69]. At the same time, the path analyzed in this paper is reflected in the innovation activities of the League of Nations joint-stock enterprises. These enterprises use digital capabilities to build a digital core platform so that all stakeholders in the industrial Internet can conduct value cocreation and sharing activities, thus realizing resource sharing and continuously

Table 8: Information transparency intermediary effect test results.

	Analyst	Innovation
Analyst		0.0566***
		(4.2991)
Digital	0.0517***	0.0417***
	(4.4945)	(3.0210)
_cons	−9.0391***	−7.4886***
	(−13.6713)	(−9.3246)
Controls	YES	YES
Year	YES	YES
Individual	YES	YES
N	9511	9511
Adj. R^2	0.668	0.801

enhancing the information transparency of enterprises and improving the innovation ecosystem of enterprises.

6. Further Analysis

6.1. Analysis of the Moderating Effect of Financing Constraints (FC) on the Impact of Digital Transformation on Enterprise Innovation. In addition to studying the two channels of digital transformation to promote innovation through the enhancement of both productivity and corporate transparency, the conditions that affect corporate innovation are also explored in this paper. In a previous study, Fan et al. found that executive equity and compensation incentives have a moderating effect on the relationship between digital strategic positioning and innovation output [70]. This study considers that it is difficult to bear the financing gap of innovation activities by relying solely on the limited internal funds of enterprises for most small and medium-sized enterprises. The investment scale of innovation activities is large, and the cycle is long. Ensuring the continuous progress of R&D projects through external financing has become an essential source of innovation for enterprises. In addition, there is information asymmetry between enterprises and financial institutions, which will bring morally hazardous and adverse selection problems, causing financial difficulties for enterprises. When enterprises have financing constraints, they will restrict the development of enterprise innovation activities.

To explore whether financing constraints inhibit enterprise innovation, referring to the research of various scholars [71], the financing constraint index Model (4) is constructed as follows:

$$P\left(\text{QUFC} = 1 \text{ or } 0 \middle| Z_{i,t}\right) = \frac{e^{Z_{i,t}}}{1 + e^{Z_{i,t}}},$$

$$Z_{i,t} = \lambda_0 + \lambda_1 \text{Size}_{i,t} + \lambda_2 \text{LEV}_{i,t} + \lambda_3 \left(\frac{CD}{TA}\right)_{i,t} + \lambda_4 MB_{i,t} + \lambda_5 \left(\frac{\text{NWC}}{TA}\right)_{i,t} + \lambda_6 \left(\frac{\text{EBIT}}{TA}\right)_{i,t}.$$

(4)

The specific meanings of the variables in the Model (4) are presented in Table 9. First, the three variables of company size, company age, and cash dividend payment rate are standardized according to the year. The listed companies are sorted according to the mean value of the standardized variables. The upper and lower tertiles are used as the dividing point of financing constraints, and the financing constraints dummy variable QUFC is determined. Listed companies with more than 66% quantiles are defined as the low financing constraints group, QUFC = 0, and listed companies with less than 33% are defined as the high financing constraints group, QUFC = 1. Second, logit regression is performed on Model (4) to fit the probability P of financing constraints per year, and it is defined as the financing constraint index (between 0 and 1). The larger the FC is, the more serious the enterprise's financing constraint problem is.

To further investigate the moderating effect of financing constraints on enterprise innovation in the digital transformation process, a moderating effect Model (5) is constructed. Model (5) introduces the interaction between financing constraints and digital transformation to explore its moderating effect. The regression results are shown in Table 10.

$$\text{Innovation}_{i,t} = \gamma_0 + \gamma_1 \text{Digital}_{i,t} + \gamma_2 FC\,(FS)_{i,t} + \gamma_3 \text{Digital} \times FC\,(FS)_{i,t} + \sum \text{Controls}_{i,t} + \sum \text{Year}_{i,t} + \sum \text{Individual}_{i,t} + \varepsilon_{i,t}.$$

(5)

According to Table 10, the regression coefficient of the interaction between digital transformation and financing constraints is negative ($\gamma_3 = -0.1788$, $P < 0.01$). The coefficient of digital transformation to enterprise innovation is positive ($\gamma_1 = 0.1225$, $P < 0.01$), indicating that high financing constraints have a negative moderating effect on enterprise innovation in digital transformation, that is, the higher the financing constraints, the weaker the impact of digital transformation on enterprise innovation. Corporate social responsibility and other behaviors can alleviate financing restrictions and increase the innovation ability of enterprises [72]. Although enterprises themselves take the initiative to seek more financing, many external factors, such as the macro environment, affect the financing conditions of enterprises. In this paper, we find that enterprises have a negative impact on innovation in digital transformation from the perspective of high financing constraints. The reason may be that digital transformation usually requires a series of investments, such as technological upgrading, equipment acquisition, and data analysis. These investment activities require large amounts of funds. If enterprises cannot obtain sufficient financing, it will be difficult to promote the process of digital transformation and limit their ability to innovate. When enterprises face unstable financing sources or more serious financing constraints, companies will face higher financial pressure or be in a competitive market due to financial constraints, and the company's innovation activities will be suppressed.

6.2. Analysis of the Moderating Effect of Financial Slack (FS) on the Impact of Digital Transformation on Enterprise Innovation.

Due to the intense uncertainty of enterprise innovation, obtaining funds through external financing is difficult. Therefore, the implementation of various strategic activities of enterprises will rely more on the support of their available funds [73]. As the financial resources enterprises have more than the current production and operation, financial redundancy can be flexibly controlled and used by enterprises. With more financial redundancy, startups are more likely to withhold resources to cope with the changing market environment to buffer operations from environmental shocks rather than invest in innovation [74]. In addition, when enterprises have more redundant funds, they tend to buy mature technology rather than innovate to reduce risks.

The moderating effect of financial slack is further examined by measuring the corporate financial ratios (cash and cash equivalents/total assets) minus the mean of the total sample financial ratios [75]. The financial redundancy variable is added to the moderating effect Model (5). The regression results show that the regression coefficient of the interaction term between digital transformation and financial redundancy is negative ($\gamma_3 = -0.0049$), which at a level of 1% is not significant, indicating that in the process of digital transformation, financial redundancy does not play a moderating role in innovation, which is consistent with the research results of other scholars [76]. This is contrary to the research results of Du et al., which is mainly because Yunzhou studies newly listed startups, which are more inclined to use unabsorbed idle funds to seek radical innovation.

6.3. Heterogeneity Analysis

6.3.1. Enterprises Are Divided According to the Nature of Property Rights.

In some medium-high-tech manufacturing industries, state-owned enterprises have taken the lead in promoting digital transformation [77]. As the backbone of national economic development, it conforms to the inevitable requirements of the digital economy era and the construction of digital China. It is also a concrete manifestation of undertaking specific missions and exerting unique advantages as a mixture of political and economic functions in the new development stage. According to the nature of enterprise property rights, enterprises are divided into state-owned and nonstate-owned enterprises. Some scholars have found that the effect of digital transformation on enterprise innovation is more remarkable in private enterprises than in state-owned enterprises [18]. In contrast, this paper uses Model (1) to test heterogeneity. The analysis of Table 11 shows that digital transformation has

TABLE 9: The meaning of the FC measurement index.

Variable name	Meaning
Size	Natural logarithm of total assets
LEV	Total liabilities/total assets
CD	Cash dividends issued by the company in the year
MB	Market value/book value
NWC	Working capital-monetary capital-short-term investment
EBIT	Interest before tax profit
TA	Total assets

TABLE 10: Test results of the moderating effect.

	Innovation	Innovation
FC × Digital	−0.1788*** (−4.8306)	
FC	0.2847*** (3.2048)	
FS × Digital		0.0355 (1.0439)
FS		−0.0049 (−0.3988)
Digital	0.1225*** (5.7431)	0.0444*** (3.2122)
_cons	−8.1539*** (−8.7873)	−7.7249*** (−9.6738)
Controls	YES	YES
Year	YES	YES
Individual	YES	YES
N	9277	9495
Adj. R^2	0.802	0.800

a significant impact on the innovation of state-owned enterprises, and its coefficient is positive ($\partial_1 = 0.0823$, $P < 0.1$). This is mainly because digital transformation constantly empowers state-owned enterprises with science and technology, which significantly impacts their innovation capabilities. However, due to the lack of human resources, technical ability and experience, the degree of digital transformation of nonstate-owned enterprises does not have a significant impact.

6.3.2. Enterprises Are Divided According to the High-Tech Level. To verify the heterogeneous performance of enterprises under different technical levels, this study divides the sample into high- and low-tech enterprises according to the Technology Industry (Manufacturing) Classification (2013) issued by the National Bureau of Statistics of China. High-tech enterprises possess abundant resources, which confer them a significant advantage in innovation during the process of digital transformation. Unlike this study, we continue to use the Model (1) test. The regression results of Columns (3) and (4) in Table 11 show that enterprise digital transformation has a stronger role in promoting the performance of nonhigh-tech enterprises [78], and its

coefficient is 0.0647. This may be because nonhigh-tech industries usually belong to traditional industries, the production and operation mode is more conventional and relatively backward, and the technology intensity, the breadth and depth of digital technology application are not as good as high-tech industries' space for digital transformation is larger. Therefore, the deep integration of digital technology with various fields of traditional industries will have a more significant effect on its traditional production and operation mode, a more noticeable effect on the improvement of its production and operation management efficiency, and a greater effect on its innovation, thus showing a more significant role in promoting the innovation of nonhigh-tech enterprises.

6.3.3. Enterprises Are Divided According to the Life Cycle. Referring to the existing domestic research, the comprehensive scores of sales revenue growth rate, capital expenditure, retained earnings, and enterprise age are selected to divide the enterprise life cycle. Considering the industry differences of listed companies in China and the actual situation in that they have passed the initial stage, the enterprise life cycle is divided into three phases: growth, maturity, and recession. Some scholars studied only the direct impact of the enterprise life cycle stage on enterprise innovation and did not explain the role of digital transformation in this relationship [79]. Based on Model (1), this paper conducts the research. As shown in Table 12, the regression results show that the regression coefficients of the digital transformation of enterprises in growth and maturity are insignificant. In contrast, the regression coefficients of the digital transformation of enterprises in recessions are positive ($\partial_1 = 0.1233$, $P < 0.1$). This is because since the company entered the mature period, due to the improvement of the company's profitability, corporate reputation, and market share, the problem of endogenous funds has been solved. The resource orientation of financial technology has helped companies attract many new investors, and exogenous capital constraints have also been alleviated. By alleviating financial problems and improving organizational systems, enterprises are strongly willing to innovate. When the enterprise is in a recession, the product market share of the enterprise decreases and competitiveness weakens. To ensure the sustainable development of the enterprise, the enterprise is more inclined to develop new products and find new competitive points and hopes to maintain its development through innovation.

6.4. Digital Transformation Promotes Sustainable Development of Enterprises through Innovation. Based on previous research, digital transformation can promote enterprise innovation, and the continuous innovation of modern enterprises aims to achieve the goal of sustainable development, which is also in response to the call of the country to "empower green upgrading with digital transformation." On the one hand, with the help of data capture, storage, and analysis, digitally transformed enterprises can help enterprises reshape business processes and improve operational

TABLE 11: Heterogeneity analysis results.

	State-owned enterprise	Nonstate-owned enterprises	High-tech enterprises	Nonhigh-tech enterprises
Digital	0.0823***	0.0309*	0.0130	0.0647***
	(3.1781)	(1.9002)	(0.6911)	(3.0844)
Controls	YES	YES	YES	YES
Year	YES	YES	YES	YES
Individual	YES	YES	YES	YES
_cons	−11.0094***	−8.0695***	−9.2970***	−6.6359***
	(−5.8622)	(−8.6587)	(−8.3295)	(−4.9705)
N	3086	6400	4381	5032
Adj. R^2	0.849	0.779	0.771	0.798

TABLE 12: Life cycle heterogeneity analysis results.

	(1) Growth	(2) Maturity	(3) Recession
Digital	0.0288	0.0290	0.1233***
	(1.0587)	(1.0852)	(4.3322)
Controls	YES	YES	YES
Year	YES	YES	YES
Individual	YES	YES	YES
_cons	−8.1170***	−5.7006***	−5.3909***
	(−4.9826)	(−3.3611)	(−3.1569)
N	3292	3021	2770
Adj. R^2	0.7940	0.8082	0.7799

efficiency. In addition, digital transformation can help enterprises optimize management strategies. Moreover, enterprises that realize digital transformation will be more resilient to changes in various operating environments, thus creating their sustainable development competitiveness.

$$\text{ESG}_{i,t} = \delta_0 + \delta_1 \text{Innovation}_{i,t} + \delta_2 (\text{Innovation} \times \text{Digital})_{i,t} + \delta_3 \text{Digital}_{i,t} + \text{Controls}_{i,t} + \sum \text{Year}_{i,t} + \sum \text{Individual}_{i,t} + \varepsilon_{i,t}.$$

$$(6)$$

The theory of sustainable development contends that corporate performance mainly depends on the company's long-term health, which is closely related to the ESG performance of the company. With the increasing frequency of risks in the current enterprise environment, ethics and other related fields, the excellent performance of ESG means that enterprises focus more on business compliance and sustainable development to avoid short-sighted behavior in enterprise development. Therefore, the sustainable development index of enterprises is measured by ESG [80]. The other variables in Model (6) remain unchanged.

The results of Column (1) in Table 13 show that the regression coefficient of enterprise innovation is $\delta = 0.0149$, which is insignificant. Therefore, enterprise innovation cannot promote the sustainable development of enterprises,

Therefore, this study further analyzes whether digital transformation can significantly promote the sustainable development of enterprises through innovation. Referring to the existing research, this paper constructs Model (6) to verify its functional analysis [18].

which may be because the long-term growth brought by enterprise innovation requires a certain amount of time [18]. In addition, the regression coefficient of the multiplication of digital transformation and innovation output is significant. At the level of 5%, the coefficient $\delta_2 = 0.0137$, indicating that digital transformation can encourage enterprises to achieve sustainable development goals through innovation channels. Considering the influence of time factors, the ESG is tested one period behind. The results are shown in Column (2). The coefficient of the interaction term between digital transformation and enterprise innovation is still positive ($\delta_2 = 0.0106$, $P < 0.1$), which can still prove that under the background of digital transformation, enterprise innovation can help enterprises take the road of sustainable development [81].

TABLE 13: Digital transformation and the enterprise sustainable development enhancement function.

	(1) ESG	(2) ESG
Innovation	0.0149 (1.1333)	0.0060 (0.4024)
Innovation × Digital	0.0137** (2.5499)	0.0106* (1.7186)
Digital	−0.0047 (−0.2129)	0.0289 (1.1379)
Size	0.1730*** (6.6991)	0.2195*** (6.8685)
Fixed	0.0388 (0.2896)	0.1897 (1.1689)
ROE	0.1061** (2.4039)	0.0302 (0.6007)
TobinQ	0.0082*** (2.7250)	0.0136** (1.9904)
Board	−0.2345*** (−2.6268)	−0.0122 (−0.1229)
FirmAge	−0.2453 (−1.2184)	−0.3180 (−1.1839)
Year	YES	YES
Individual	YES	YES
_cons	1.2043 (1.4747)	−0.1351 (−0.1287)
N	9188	7731
Adj. R^2	0.504	0.502

7. Conclusion and Discussion

7.1. Research Conclusions. The rapid development of information technology has promoted the digital transformation of enterprises, spawned a series of new enterprise forms, and brought significant changes to human social life. Accelerating the construction of an innovative country is a primary strategic task to implement the new development concept and build a modern economic system. In this context, it is of great practical significance to examine the impact of digital transformation on enterprise innovation. This paper takes Shanghai and Shenzhen A-share listed companies from 2013 to 2021 as the research object, uses text mining technology to construct an enterprise digital transformation index, and examines the role of digital transformation in promoting enterprise innovation. Finally, the following conclusions are obtained:

(1) There is a significant positive relationship between digital transformation and enterprise innovation. (2) The role of digital transformation in promoting enterprise innovation can be achieved by improving enterprise productivity and enhancing enterprise information transparency. Digital transformation can improve the TFP of enterprises and provide more resources and capabilities for innovation. At the same time, digital transformation can also strengthen the information transparency of enterprises and provide accurate market intelligence and technical guidance to promote the innovation and development of enterprises. These factors work together to help enhance the innovation ability and competitive advantage of enterprises. (3) Considering that innovation requires considerable funds, from this perspective, corporate financing constraints and financial redundancy are introduced into the empirical analysis. Excessive financing constraints hinder the role of digital transformation in promoting enterprise innovation. Because enterprise managers may retain idle funds to cope with unexpected situations, financial redundancy cannot promote enterprise innovation in digital transformation. (4) The impact of digital transformation on enterprise innovation is more significant in state-owned and nonstate-owned enterprises. Nevertheless, compared with enterprises in growth and maturity, the impact of enterprises in recessions is more significant. (5) In the digital transformation process, enterprises can achieve sustainable development goals faster through innovation activities.

These findings deepen our understanding of the enterprise innovation chain in the research content and have far-reaching policy significance for further deepening digital construction and maximizing the use of digital dividends to stimulate the innovation potential of enterprises.

7.2. Theoretical Significance. Most research on digital transformation focuses on enterprises in developed economies, while enterprises in transition economies are relatively poor in terms of organization, technology and resources. Therefore, transition economies face more challenges in digital transformation, which provides an excellent empirical environment for scholars' research. This paper provides convincing evidence and makes the following theoretical contributions:

This study promotes digital development and innovation research and expands the mediating and moderating variables of digital transformation and enterprise innovation. When considering the impact of digital transformation on enterprises, previous studies have mostly focused on enterprise value. By focusing on the element of enterprise innovation, this paper enriches the relevant theories of technology communication theory, innovation ecology theory, process reengineering theory, and so on. In addition, we respond to the study of many scholars who argue that future analysis can empirically examine how digital transformation affects the sustainable development of enterprises. Innovation has become the core source of sustainable competitive advantage.

Second, this paper studies enterprise productivity as an intermediary mechanism to explain digital transformation and enterprise innovation. This research enriches Schumpeter's innovation theory, which is reflected in this study. Innovation is a revolutionary change and can create new value. In addition, this paper also discusses the intermediary effect of enterprise information transparency, which provides theoretical support for the "information view" and "investment view." Information transparency refers to the quality and efficiency of a series of circular processes from information production, information acceptance, information supervision, and information quality improvement until the information is accepted by investors and

evolves into an investors' decision-making basis, which is conducive for investors to master more information to invest more funds for the digital transformation of enterprises to increase innovation activities. Finally, the heterogeneity analysis of enterprises with different natures and development stages is carried out, which provides a more detailed and comprehensive understanding of different types of enterprises to help enterprises innovate by implementing strategic measures.

7.3. Practical Implications. This study also has some management implications for enterprises and governments. First, given that digitalization is a prerequisite for enterprise innovation, enterprises should focus on equipping and integrating digital technology to establish a sound digital infrastructure for enterprise innovation. Enterprises should actively explore the application of digital technology. Second, enterprises should improve productivity through digitalization and strengthening information transparency. On the one hand, enterprises can use digital technology to contact customers and create more business opportunities. On the other hand, the digital transformation of enterprises can connect all departments. On this basis, employees strengthen cooperation and improve the integration of enterprises to enhance innovation.

Government departments should establish and improve relevant supporting policies for the digital transformation of enterprises, such as tax reduction, guiding enterprises to use digital technology, and promoting the deep integration of enterprises and digital technology to ensure the industrial upgrading of transition economies and inject new vitality into enterprise innovation.

7.4. Research Limitations. Although the research samples used in this study include Chinese enterprises of different types and industries, they only come from Chinese enterprises listed on the Shanghai and Shenzhen exchanges. This study does not focus on enterprises in other countries. In addition, due to environmental and cultural differences, it may not be prudent to apply this study to other countries. Second, this paper only studies the mediating effect of enterprise productivity and information transparency on the relationship between digital transformation and enterprise innovation. Nevertheless, other factors may also play an important role. Therefore, we call on more scholars to participate in the study together to think more deeply.

Data Availability

The data presented in this study are available from the authors upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Jiqiong Liu was responsible for conceptualization and methodology and wrote the original draft. Chunyan Liu was responsible for conceptualization and methodology, wrote the original draft, and reviewed and edited the article. Shuai Feng was responsible for supervision and methodology and reviewed and edited the article.

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