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RETRACTED: Digital Transformation and Enterprise Resilience: Evidence from China

Dong Wang * and Shengli Chen

School of Management, Xi'an University of Finance and Economics, Xi'an 710100, China
* Correspondence: wsd@xaufe.edu.cn

Abstract: Digital transformation has become a key strategy for enterprises to enhance resilience in effectively responding to external shocks and achieving sustainable development in the context of the global spread of the epidemic and the increase of uncertainties in external environments. In this paper, the impact and mechanism of digital transformation on corporate resilience are examined based on data of listed Chinese companies from 2011 to 2020. Our results results reveal that digital transformation can significantly enhance corporate resilience. This conclusion remains unchanged after controlling for endogeneity issues and performing various robustness analyses. Digital transformation has heterogeneous effects in the dimensions of corporate property rights, industries, and regions, with state-owned enterprises, manufacturing, and eastern enterprises benefiting more. Digital transformation primarily reinforces corporate resilience through mechanisms that improve human capital, strengthen innovation capabilities, ease financing constraints, and enhance internal control. Therefore, the government must guide macro policies, pay attention to the leading role of state-owned enterprises, and narrow the regional digital divide to better enact digital transformation and promote corporate resilience. Simultaneously, in the process of digital transformation, enterprises should combine the characteristics and development stages of their industry by exploring the development requirements and strategically implementing them in stages in a targeted manner. The findings of this paper provide new empirical evidence for the economic impact of enterprise digital transformation, as well as useful inspiration for enhancing enterprise resilience and promoting high-quality development.

Keywords: digital transformation; enterprise resilience; digital economy; digital technology

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1. Introduction

Currently, China is in a period of intertwined economic contradictions at home and abroad, and there are many uncertainties in the business environment of enterprises [1]. From one perspective, the trend of anti-globalization has intensified, trade frictions have frequently occurred, and the risk of a "disruption of supply" in the industrial and supply chains has significantly increased [2]. From another perspective, China's economy is in a critical transition period from a high-speed growth stage to a high-quality development stage. Structural, institutional, and cyclical economic contradictions are prominent, and the downward pressure on the economy continues to increase [3]. The ups and downs of the COVID-19 epidemic have exerted a huge impact on society and people from all walks of life. In such a highly turbulent and complex business environment, knowing how to survive or even turn "dangers" into "opportunities" to achieve greater development has become a focus of attention of people from all walks of life. Theoretical and practical studies have suggested that corporate resilience can not only effectively manage crises but also become a source of sustainable, competitive advantage and success for companies in a turbulent and changing market environment [4–10].

Concurrently, digital technology has flourished and gradually penetrated all aspects of enterprises, reconstructing the capabilities of enterprise resource allocation and market

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response, as well as risk management, control, and trend insight. Digital transformation has become a crucial strategy for enterprises to enhance the resilience necessary to wrestle from external uncertainties. In theory, the digital transformation of enterprises can drive the remodeling and reform of enterprise organizational management models from three aspects: connecting organizations, aggregating data, and filtering users to improve the ability of enterprises to handle adverse events [11]. Some enterprises have established effective connections with users, internal levels and inter-departmental enterprises and all aspects of the supply chain through the application of digital technology. This has contributed to a remarkable acceleration in the speed of recovery and rebound of enterprises in crisis, especially in the early stage of the new crown pneumonia outbreak [12]. Unfortunately, the current research on the relationship between digital transformation and corporate resilience still emphasizes theoretical exploration, and there is little relevant empirical research. Hence, how exactly does digital transformation affect corporate resilience in practice? Would this effect be significantly different under conditions of heterogeneity? Furthermore, what is the mechanism behind it? Accurately answering these questions will not only help deepen the understanding of the effects of digital transformation on enterprises but also provide decision-making references for improving Chinese enterprises' ability to respond to external shocks.

Digital transformation is not a new concept. As early as 1991, Morton pointed out in his pioneering research that the application of digital technology would bring about radical changes in the production, operation, management, and service modes of enterprises [13]. Additionally, Vial conceptualized the digital transformation of enterprises as the process of realizing major business improvement through the combination of information, computing, communication, and other modules [14]. The digital transformation of enterprises will bring extensive and far-reaching impacts. From a macro perspective, the digital transformation of enterprises will stimulate profound changes in society and industry and can enhance the overall total productivity of society [15], promote the upgrading of the industrial structure [16], and strengthen the social welfare of low-material capital groups [17]. From a micro perspective, digital transformation can reinforce the operational efficiency of enterprises, such as through production automation [18], business process improvements [19], cost savings [20], and increased labor specializations [21]. Moreover, it can improve corporate organizational performance, such as innovation [22], financial performance [23], the growth of companies [24], and capital market performance [25]. There are also some potential challenges with the widespread application of digital technologies, mainly in the data security and privacy areas [26].

It is difficult to discuss the effects of enterprise digital transformation from an empirical perspective since there is a lack of scientific and accurate measurement methods for digital transformation at the micro-enterprise level. However, some researchers have conducted tentative exploration work, which can generally be summarized into two methods: the text analysis [27] and the survey questionnaire [28]. The former usually uses "0–1" variables to measure the digital transformation of enterprises, but it lacks a description of the "intensity" of digital transformation. The latter has limited representation due to too few data samples. Through the text analysis method, Wu Fei et al. measured the digitalization level of enterprises by logarithmizing the word frequency while obtaining digital transformation word frequencies [25]. This inspired the present study to characterize the intensity of the digital transformation of enterprises.

The term "resilience" originated from engineering mechanics. It indicates the property of a material to return to its original state after being subjected to pressure and changes in its shape. In 1973, the ecologist Holling innovatively applied the concept of resilience to the ecology field [29]. Since then, the concept of resilience has been gradually applied to disciplines such as psychology, economics, urban and rural planning, and environmental science. In recent years, external shocks have become more frequent, and the VUCA (variable, uncertain, complex, and ambiguous) characteristics of the market environment have become the norm. Many researchers have paid attention to the concept of corporate

resilience, treating it as a key variable to measure the ability and quality of companies to respond to adverse events [30,31]. While there is no mature and authoritative statement on the definition of corporate resilience, Gallopin believed that corporate resilience is the ability of an enterprise to adopt its own resources and capabilities to resist and adapt to external shocks in the face of adversity [32]. Additionally, Sanchis and Poler defined enterprise resilience as the ability to proactively respond and adapt to shocks and adjust and recover from disruptive events [33]. Although the above definitions differ in expression, their core includes two basic aspects: resistance and recovery (adaptation).

The influencing factors of corporate resilience can be divided into three levels: individual, corporate, and environmental. Among them, the individual level mainly includes managers' personality characteristics and cognitive level [34]; the enterprise level consists of governance status and strategic decision-making [35], crisis learning [36], and innovation abilities [37]; the environmental level is composed of the social trust degree [38], investor protection system [30], and government financial support [39]. The characteristics of enterprises themselves are the fundamental factors influencing their resilience.

Digital transformation can have a positive effect on corporate resilience. On the theoretical side, Han and Trimi argued that digital transformation could improve the vertical cooperation of small and medium enterprises (SMEs) with partners, suppliers, and customers, as well as horizontal cooperation with competitors and knowledge-creating institutions, such as universities, which improves their organizational agility, adaptability, and resilience to grapple with the complex and changing market environment [40]. Moreover, digital technologies can improve companies' understanding and adaptability to environmental changes. For example, big data constitutes the basis of data analysis and processing, which assists enterprises in predicting and identifying external risks [41]. Digital technologies, such as artificial intelligence, can help enterprises form intelligent decision-making in a crisis and improve the resilience of supply chains [42]. Regarding empirical evidence, Jiang Luan et al. investigated the relationship between digital transformation and corporate resilience by distributing questionnaires. Their study revealed that corporate digital transformation enhances corporate resilience through two key channels: exploratory and exploitative innovation [43]. The research on the relationship between digital transformation and enterprise resilience focuses on the theoretical level, and there is little empirical research. Although some researchers have constructed an empirical analysis framework for the two innovations, digital transformation may also affect corporate resilience through other channels. Therefore, a more systematic and rigorous analysis of the relationship between the two is required.

Based on a sample of listed A-share companies from 2007 to 2020, keywords related to "digital transformation" were captured from the text information of the company's annual reports. A comprehensive evaluation system was constructed for digital transformation and corporate resilience, and the impact of digital transformation on corporate resilience was further explored in this paper. First, the analysis results of this paper unveiled that digital transformation can improve enterprise resilience. In addition, a series of tests were performed, such as sub-dimension testing of digital transformation indicators, excluding municipal samples but adding industry and year as joint fixed effects and endogenous processing. The results were all robust. Second, the mechanism analysis implied that digital transformation mainly enhanced the resilience of enterprises by improving human capital, strengthening innovation capabilities, easing financing constraints, and reinforcing internal control. Third, the heterogeneity analysis demonstrated that state-owned enterprises, manufacturing enterprises, and enterprises in the eastern region had a higher degree of digital transformation and presented a more significant impact of digital transformation on enterprise resilience.

In summary, the contributions of this paper are summarized as follows. (1) By using the data of China's listed A-share companies from 2007 to 2020, the impact of digital transformation of enterprises on resilience was deeply analyzed, as well as its mechanism, from both theoretical and empirical aspects. These analyses provide new empirical evidence

and enrich research on enterprise resilience. (2) The text analysis in machine learning and the quantitative evaluation entropy weight TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) methods were innovatively combined to more accurately and scientifically describe the intensity of digital transformation. The results provided a useful reference for subsequent quantitative research on enterprise digital transformation. (3) The three factors of corporate property rights, industry attributes, and ... were introduced into empirical analysis to clarify further the heterogeneity of the impact of digital transformation on corporate resilience and the root causes behind it. This will prospectively facilitate policymakers' decision-making in differentiating the construction of policy measures.

The rest of the paper is organized as follows. Section 2 presents the theoretical analysis and research hypothesis. The model and data are introduced in Section 3. Next, empirical tests are performed in Section 4, and the main empirical and robustness test results are reported. Section 5 details the heterogeneity test. Afterward, the mechanisms behind the empirical results are discussed in Section 6. Finally, conclusions are drawn in Section 7.

2. Theoretical Analyses and Research Assumptions

2.1. Digital Transformation and Enterprise Resilience

Marx's theory of economic crisis believes that the economic crisis cycle includes four stages: Crisis, depression, recovery, and boom. In the recovery stage, companies with a long-term vision will step up technological improvement, improve production efficiency, reduce production costs, and obtain excess profits [44]. The theory of dynamic capabilities holds that, in a complex and turbulent market environment, enterprises must continuously improve their innovation capabilities through knowledge management and learning while integrating their own resources and capabilities to enhance their core competitiveness and improve business operations continuously. Management efficiency is the only approach to obtaining a sustainable competitive advantage in an uncertain market [45,46]. As a whole, corporate resilience includes at least two aspects: (1) the ability to respond to emergencies, which mainly depends on the product value, technology, and management level of the company; (2) the ability of sustainable development, that is, the ability of the enterprise to continuously adapt, learn, and innovate to achieve a spiral upward, which depends on the human capital accumulation ability of the enterprise.

The first ability of digital transformation's response to enterprise emergencies is the application of digital technology, which can improve the level of automation and intelligence in the production and operation processes of enterprises, as well as effectively strengthen production efficiency, reduce product development and manufacturing costs, and shortening market time. In the event of a crisis, these advantages can help companies quickly allocate existing resources and capabilities and engage in new production activities to capture and create opportunities in the face of adversity to achieve unconventional growth. Second, external shocks may destroy the original communication channels of the enterprise's organization, making the connection between people within the enterprise fragmented. Moreover, activating enterprise resilience requires effectively connecting the organization from the inside out. Digital technology alters the original cross-departmental and cross-level interaction modes, which effectively connects separate business modules and units into a whole, and remarkably enhances the connection efficiency within the enterprise's organization. This optimizes the organization's business processes and decision-making in an emergency situation while bettering the enterprise's emergency response capabilities [46]. Finally, enterprises can adopt digital technology to achieve in-depth analysis and the mining of massive data. This endows enterprises with powerful data monitoring, analysis, processing, and transmission capabilities and strengthens enterprises' ability to identify and perceive external risk factors. It can help companies identify possible crisis events and respond quickly to them, especially with the analysis and processing capabilities when a shock occurs. For example, IT solutions (big data or machine learning)

in data analysis can contribute to better decisions for companies and quick responses to changes in the environment [47].

Based on the perspective of the impact of digitalization, digital transformation has changed the traditional business logic on the sustainable development of enterprises. First, digital transformation has assisted enterprises in the digital age and has helped them achieve healthy growth in a treacherous market environment by enabling the ...ment of new business models, developing new market opportunities, addi...g new bus...ss segments, and increasing their market share and profits [48]. Second, ...e deep integrati...n of emerging digital technologies in enterprise production, operati...nd manageme... make it difficult for the resources and capabilities of enterpris... to be i...ated by pee...s. Additionally, it promotes enterprises to build core competiti...e heterogene...resou...es and resource-protection mechanisms, which is conducive ...the ente...prises' ac...ment in attaining sustainable, competitive advantages. Thi...d, ...the pr...ce...s of dig...al transformation of enterprises, the widespread deploym...t of sm...devices wi...occupy the jobs that originally belonged to low-end labor, a...d the applic...n of em...erging digital technologies will increase the demand for hig...lity labor. The...or..., it improves the overall human capital level of the enterpris...and pr...ides a strong i...ellectual guarantee and talent support for the enterprise to ...nduct new ...oduction activities and achieve sustainable development. Fourth, di...ital technology res...pes the internal and external environments of enterprise innovati...ns, as well as optimizes ...e process and mode of innovations by accelerating the modul... trends and collaborations of R&D activities, promoting the development of innovation a...ivities, and provi...ling a steady stream of the impetus for the sustainable development ...enterprises. Th...erefore, Hypothesis 1 is proposed in this paper.

Hypothesis 1 (H1). *Th... ...ransformation of enterprises improves the ability of enterprises to cope with crises and sustai...able de...pment, thus effectively enhancing the resilience of enterprises.*

2.2. The Im... Mechanism... Digital Transformation on Enterprise Resilience

Di...ital tr...sformation...s of great significance for enhancing corporate resilience and mai... enhanc...s corporate ...silience by improving human capital, strengthening innovation ca...ilit... ...fin...ncing constraints, and reinforcing internal control. Its influence pa...h is ill...inated in Figure 1.

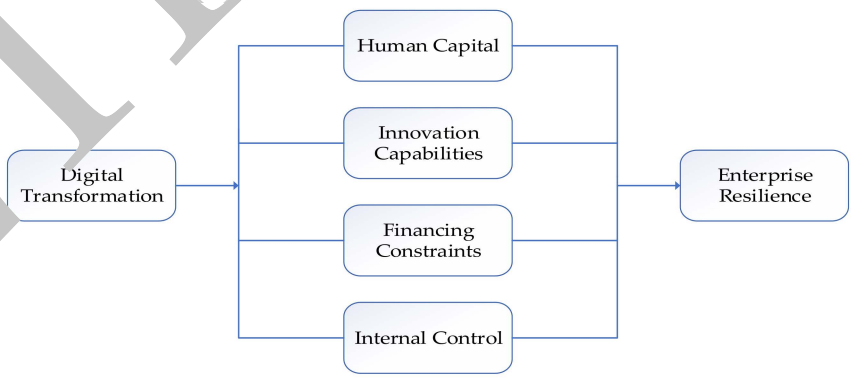

Figure 1. The impact path of digital transformation to improve enterprise resilience.

2.2.1. Digital Transformation, Human Capital, and Corporate Resilience

Digital transformation enhances corporate resilience by increasing the level of human capital. First, digital transformation will promote the combination of labor and technology within the enterprise so as to release a synergy effect of humans and machines and significantly change the traditional way of accumulating human capital. Traditional enterprises accumulate human capital mainly through "learning by doing" and investment in training. In enterprises with a high degree of digitalization, labor based on digital technology

expands the knowledge boundary that traditional labor has difficulty reaching and can supplement the existing human capital stock. Additionally, the application of emerging digital technologies will accelerate the replacement of low-end labor while increasing the demand for high-quality labor, forming a complementarity and optimized structure of human capital [49]. Finally, the application of digital technology can facilitate employees to share their experience and knowledge, realize the flow and sharing of tacit knowledge, and reduce the threshold and cost for employees to acquire knowledge, which ultimately allows for the improved quality of human capital [50].

Furthermore, human capital can reinforce corporate resilience. First, abundant human capital is a guaranteed foundation for enterprises to perform new production, operational, and innovational activities after being impacted, and it better supports an enterprise's adaptability to changes in the environment. Second, resource-based and high-level echelon theories suggest that, in an enterprise organization, having an irreplaceable and difficult-to-imitate senior management team can yield a unique competitive advantage and help enterprises stand out in a fierce market environment. Third, in the event of adverse shocks, corporate managers with higher education levels tend to consider an enterprise's crisis more deeply and comprehensively and formulate more scientific, reasonable, and long-term emergency plans that help reduce the damage of external shocks. Highly educated corporate managers can also reflect and learn from their experiences during a crisis and thus assist enterprises in strengthening their ability to adapt to the financial crisis. Therefore, Hypothesis 2 is proposed.

Hypothesis 2 (H2). *The digital transformation of enterprises can enhance resilience by improving the level of human capital.*

2.2.2. Digital Transformation, Innovation Capability, and Corporate Resilience

Digital transformation can improve corporate innovation capabilities and hence better corporate resilience. In an uncertain business environment, innovation is the catalyst for companies to recover from various crises and build long-term competitive advantages quickly. External shocks will lead to creative destruction and resource release. Enterprises with stronger innovation capabilities will use existing knowledge to discover new opportunities, make adaptive changes faster, and form new comparative advantages, thus contributing to the opening of new growth paths and can be employed as leverage in future development [51]. The digital transformation of enterprises can improve their innovation ability. Firstly, the application of digital technology from the perspective of optimizing resources can achieve the precise matching of market demand and obtain a large amount of consumer preference information for performing more targeted R&D investments and reaching demand-oriented innovations [52]. Additionally, digital empowerment from the perspective of cost reduction helps realize the low-cost penetration of knowledge and information, acceleration of the flow and search efficiency of resource elements, and can remarkably decrease the enterprise's innovation costs. Finally, enterprises utilizing the advantages of data integration and digital technology from the perspective of promoting collaborative innovation help break internal boundaries, expand the exchange of data and knowledge elements within the enterprise, and promote collaborative innovations [53]. Therefore, Hypothesis 3 is presented.

Hypothesis 3 (H3). *The digital transformation of enterprises can enhance resilience by promoting innovation capabilities.*

2.2.3. Digital Transformation, Financing Constraints, and Corporate Resilience

The digital transformation of enterprises can ease corporate financing constraints and thus enhance corporate resilience. Capital is the most imperative resource for an enterprise's production, operation, and resistance to shocks in adverse events. Financing capability is the key to an enterprise's survival and long-term development. The more

financing channels an enterprise has, the lower the threshold for financing, the less restrictive the enterprise is to allocate existing resources and capabilities fully, and the higher the likelihood of grasping new market opportunities. With more coping means, enterprises can not only withstand the negative impact of external shocks but also perform effective production and investment using existing resources and quickly recover and rebound from a crisis. However, China's financial system is still not perfect, and e[illegible] are faced with severe financing constraints. According to the World Bank's [illegible]urvey repo[illegible]n listed companies in dozens of countries around the world, about three [illegible]quarters of Chin[illegible]s listed companies indicate financing constraints as a primary challen[illegible]e, [illegible]ich is the highe[illegible] among all surveyed countries. Various industries are accelerat[illegible]g the p[illegible]ess of digit[illegible]l transformation, especially the financial industry, which has [illegible]ntered the de[illegible] water a[illegible]ea and dramatically promoted the construction and develop[illegible]ent of the digital cr[illegible] system. Therefore, financial institutions can evaluate credit ass[illegible]ss[illegible]nt risk[illegible] through th[illegible] "digital footprint" of enterprises to alleviate the "dislike the p[illegible]oor a[illegible]ve the rich" behavior in traditional bank credit and enhance the availabilit[illegible]y of financial se[illegible]es for s[illegible]all and micro enterprises [54]. Additionally, companies with [illegible]igher degree o[illegible]i[illegible]zation are easily favored by governments and financial institu[illegible]ons. F[illegible] companies th[illegible] successfully implement digital transformation frequently ha[illegible]e b[illegible]tter pros[illegible]ts and advantages in the digital age and are more likely to obtain go[illegible]ernm[illegible]ent financial [illegible]pport. As a result, corporate financing thresholds and financing [illegible]osts can be significantly [illegible]educed. Second, enterprises with a high degree of digitalizatio[illegible] can also easily acquire the focus of financial institutions. Not only can they more easily ob[illegible]in investment fro[illegible]n financial institutions, but they can also obtain greater discounts on l[illegible]n interest rates, which helps to resolve the financing difficulties of enterprise developme[illegible]55]. There[illegible]re, Hypothesis 4 is presented.

Hypothesis 4 (H4). *Th[illegible] transformation of enterprises can enhance resilience by easing financing constraints.*

2.2.4. Digit[illegible] Transformat[illegible]n, Internal Control, and Corporate Resilience

Di[illegible]gital tr[illegible]sformation [illegible]an enhance the internal control of enterprises, which, in turn, rein[illegible]ces ente[illegible]prise resilie[illegible]e. Internal control is a crucial measure to reduce the risk of [illegible]illegal [illegible]erp[illegible]ise[illegible]vent financial information fraud, and promote the sustainable develop[illegible]ment o[illegible]f [illegible]nterprises. It not only affects the current operating conditions of enterprises but is also closel[illegible]y related to future development prospects. Moreover, Xie et al. believed that internal control[illegible] can increase the level of operation, management, scientific decision-making, [illegible]d risk-preve[illegible]ntion capabilities of enterprises while assisting them in identifying various ris[illegible]s caused by rapid changes and avoiding the impact of adverse events in the external envir[illegible]ent [56,57]. Wang and Han suggested that an enterprise with relatively complete intern[illegible]al control has stability in strategy formulation, which can improve the sustainable development ability of enterprises, maximize the efficiency of resource utilization, and prevent the enterprise from blindly developing non-core businesses, as well as lower the risk of decline due to frequent changes in strategy [58]. Therefore, to effectively play the role of internal control, it is not only necessary to pay attention to and improve upon the quality of middle- and high-level internal control personnel, but also to adopt advanced technology in internal control management. The application of digital technology in internal control can remarkably enhance the efficiency and agility of all aspects of internal control, as well as dynamic decision-making in enterprise operation and management, which is ultimately more conducive to the capture and identification of internal and external risks during development. Evaluation and feedback can help internal control personnel detect and grasp accidental errors in a timely manner, which are not subjectively caused by all parties within the enterprise. Concurrently, the application of digital technology in the internal control link can change the overall idea of "passive discovery" to "active identification." Consequently, enterprises can more accurately understand the early signals, judge the destructive effects, prevent the spread of risks, and eliminate the hidden dangers of the

crisis in the budding stage, contributing to the alleviation of adverse effects from the crisis. Therefore, Hypothesis 5 is proposed.

Hypothesis 5 (H5). *The digital transformation of enterprises can enhance resilience by strengthening internal control.*

3. Study Design

3.1. Model Settings

First, to verify the impact of digital transformation on enterprise resilience, the following measurement model was constructed:

$$Res_{it} = \alpha + \beta Dige_{it} + \gamma\, Controls_{it} + \delta_I + \lambda_Y + \varepsilon_{it} \quad (1)$$

The explanatory variable, *Res*, indicates the enterprise resilience; the core explanatory variable, *Dige*, denotes the enterprise digital transformation index; the parameter β depicts the impact of digital transformation on enterprise resilience and *Controls* represents the regional- and enterprise-level control variables. The industry-fixed effect δ_I and year-fixed effect λ_Y are added to the econometric model to mitigate the impact of industry and year factors on enterprise resilience. ε is the random disturbance term. A robust standard error estimation regression model was used to improve the robustness of the empirical test results.

Furthermore, the specific steps to examine the mechanism of digital transformation on enterprise resilience are described as follows. The first step is to observe whether the coefficient of digital transformation, *Dige*, in Equation (1) is positive. The second step is to construct the regression equation of digital transformation, *Dige*, on the mediating variable, *Inter*, and observe whether the coefficient of digital transformation, *Dige*, is positive. The third step is to form the regression equation of digital transformation, *Dige*, and the mediating variable, *Inter*, on enterprise resilience, *Res*, and judge whether the mediating effect exists by observing the significance and magnitude of the regression coefficients, such as digital transformation *Dige* and mediating variable *Inter*. The complete mediation effect model is as follows:

$$Inter_{it} = b_0 + b_1 Dige_{it} + \beta Controls_{it} + \delta_I + \lambda_Y + \varepsilon_{it} \quad (2)$$

$$Res_{it} = c_0 + \lambda Inter_{it} + c_1 Dige_{it} + \beta Controls_{it} + \delta_I + \lambda_Y + \varepsilon_{it} \quad (3)$$

where *Inter* denotes the intermediary variable, which takes the four variables of human capital (*Hum*), innovation ability (*Inv*), financing constraints (*Ww*), and internal control (*Ic*).

3.2. Variable Measurement and Description

3.2.1. Core Explanatory Variable

This section explains the Enterprise Digital Transformation Index (*Dige*) variable. There are two measurement methods of an enterprise's digital transformation that can be summarized from the existing literature: text analysis and survey questionnaire. The former usually collects the text data of the company's annual report and uses a 0–1 variable to measure whether the company has implemented digital transformation, but it cannot describe the intensity of the company's digital transformation. It is difficult to consider the latter method's research conclusions as representative due to the small sample sizes in the literature. Therefore, this paper innovatively combined the text analysis and entropy weight TOPSIS methods. The text analysis method was used to obtain the digital transformation data of enterprises, and the entropy weight TOPSIS method was employed to scientifically and accurately measure the intensity of the digital transformation of enterprises, thereby establishing a more scientific and accurate measurement model. The steps are detailed as follows. First, a dictionary of the digital transformation of listed Chinese companies is established. The relevant stems are provided by Yuan et al. [21] and Wu et al. [25], wherein

all stems are divided into five dimensions: artificial intelligence, big data, cloud computing, blockchain, and digital technology applications, so as to determine the corresponding root-screening target (see Figure 2). Second, Python software is adopted to collect the annual reports of listed companies from 2007 to 2020 on the official website of the Shanghai and Shenzhen Stock Exchanges and to convert them into text format. Third, the Jieba library in Python is employed to perform word segmentation, root recogniti[illegible], [illegible]ount all word frequencies, as well as delete expressions with negative word prefixes, su[illegible]s "no." Finally, each of the five dimensions in the root of all samples is co[illegible]nted, the weigh[illegible] each index is calculated by the entropy weight method, and the TO[illegible] method is use to evaluate the pros and cons of each evaluated object to obta[illegible] the E[illegible]rprise Digit[illegible] Transformation Index, *Dige* (the detailed formula is provided in Appendix [illegible]. The ke[illegible]el density estimation of *Dige* is illustrated in Figure 3.

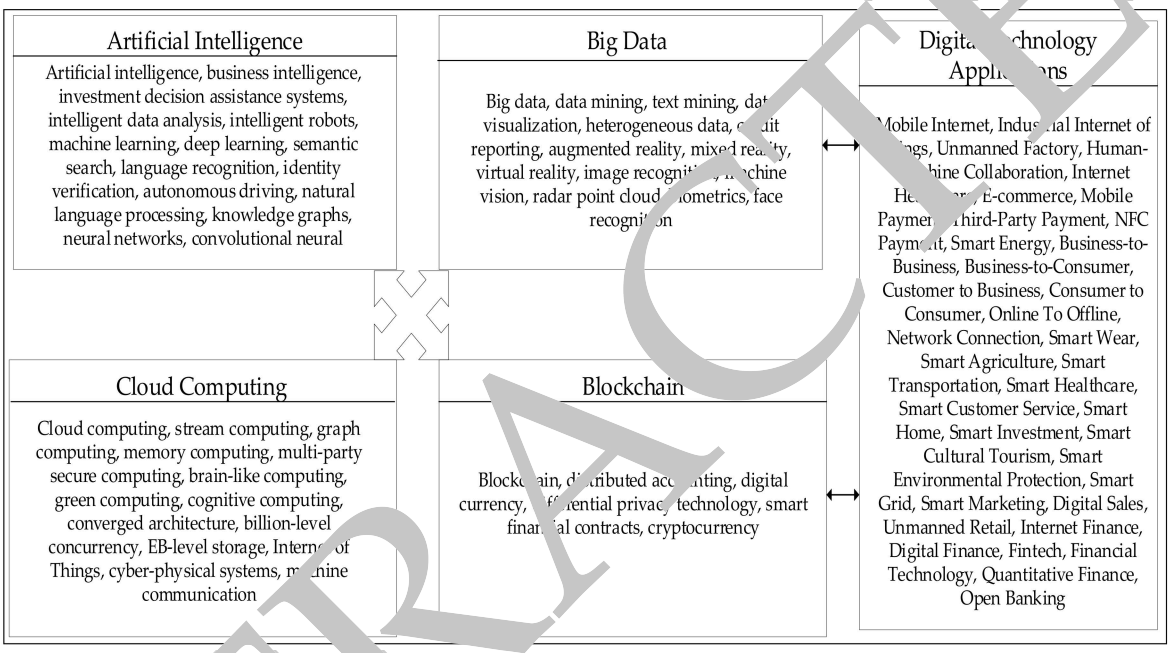

Figure 2. The [illegible]t characteristics of enterprise digital transformation.

[illegible]2. Explaine[illegible] Variable

[illegible]his section explains the Enterprise Resilience (*Res*) variable. The existing literature mainly [illegible]easures corporate resilience through the following methods: One is the long-term perfo[illegible]mance of the company, such as its financial stability, sales growth, and survival rate. The second is the use of the firm's performance under specific shocks, such as the extent of losses and recovery in the Global Financial Crisis. In this paper, the long-term development resilience of enterprises is investigated, and the first method is more suitable for the present research. However, long-term performance indicators of companies, such as the sales growth rate, cannot capture the differences and correlations between the resilience of individual companies and the resilience of other companies. Therefore, the core variable method for measuring urban economic resilience introduced by Martin [59], a new economic geographer, was incorporated into our research on enterprise resilience measurement. This method has been widely applied to regional economic resilience measurement research and has a considerable representative sturdiness and reliability. Additionally, the concept of corporate resilience is similar to the concept of regional economic resilience: "Regional economic resilience is the ability of a regional economy to resist shocks and quickly embark on a new growth path after suffering external shocks," which lays a foundation for the introduction of this method. The core idea of the calculation is to compare the development of a single enterprise with the development of all enterprises. When the development

level of an enterprise is better than the average development level of all enterprises, its resilience is high; when the development level of an enterprise is lower than the average development level of all enterprises, its resilience is low. In this paper, the representative indicator of the total sales revenue of the enterprise is adopted to describe the development level of the enterprise, and it is brought into the model to measure enterprise resilience. The specific formula is:

$$Res = (\Delta E_{SOLE}/E_{SOLE})/(\Delta E_{ALL}/E_{ALL}) \quad (1)$$

where *Res* indicates the resilience of the company, E_{SOLE} denotes the total sales revenue of the company in the previous year, E_{ALL} represents the increase in the company's revenue this year, $Res > 0$ signifies the total sales revenue of all companies in the previous year, and ΔE_{ALL} stands for the increase in the sales revenue of companies this year. $Res > 0$ suggests that corporate resilience was relatively high; $Res < 0$ suggests that corporate resilience was relatively low.

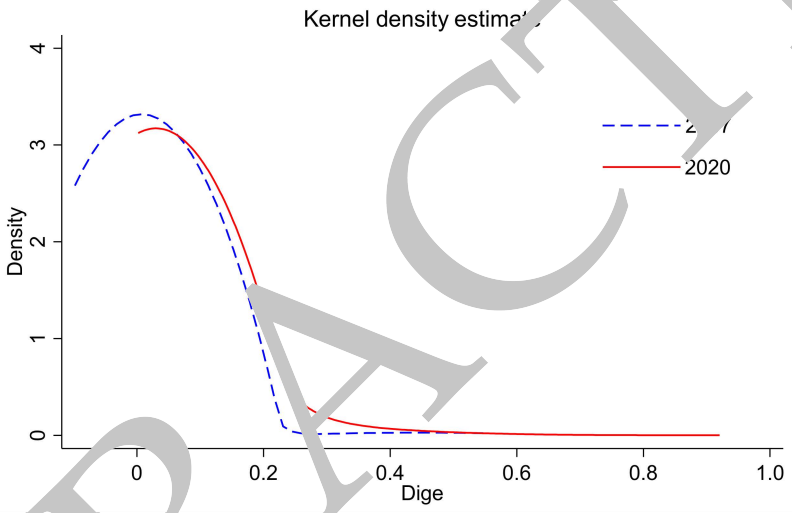

Figure 3. Kernel density estimation of digital transformation variables.

3.2.3. Mediator Variables

① Human capital (*Hum*): By drawing from the practice of Wang and He [60], the entropy method is used to measure the human capital of the enterprise and calculate the comprehensive level of the enterprise in three dimensions, such as executive compensation, R&D personnel scale, and R&D investment. Among these, the level of executive compensation reflects the value of executive human capital, the scale of R&D personnel reflects the stock of technical human capital, and the R&D investment reflects the intensity of investment and the level of human capital protection. ② Innovation ability (*Inv*): by drawing from the practice of Ma [61], the total number of patent applications for inventions, utility models, and designs of enterprises is used to measure the innovation ability of enterprises. ③ Financing constraints (*Ww*): the negative number of the White-Wu index (abbreviated as *Ww*) is selected to measure the degree of financing constraints of enterprises, which is mainly composed of several enterprise-related financial indicators, such as the ratio of net cash flow to total assets, dividend payments, and the ratio of long-term liabilities to total assets. ④ Internal control (*Ic*): the internal control index provided by the Bodi Big Data Research Center is used to describe the internal control level of the enterprise.

3.2.4. Control Variables

According to the existing literature, the control variables are selected from the regional and enterprise levels. The regional-level control variables are ① opening to the outside world (*Open*), which is measured by the ratio of the total import and export volume of

the registered province of enterprises to GDP. ② Economic development (*Gdp*), which is measured by the logarithmic representation of the GDP of the province where enterprises are registered. ③ Infrastructure (*Inf*), which is measured by the ratio of the length of the highway in the province where the enterprise is registered to the total area of the province. The enterprise-level control variables are ④ enterprise size (*Size*), which is measured by the logarithm of the total number of employees in the enterprise. ⑤ Operati... ...iency (*Oper*), which is measured by the comprehensive score of enterprise as...et turnover ...te, average asset occupancy, and cash turnover rate calculated by the e...tropy method. ... Intangible assets (*Int*), which is represented by the ratio of the i...ta...ible assets of th enterprise to the total assets. ⑦ Enterprise debt (*Lev*), which is m...asured ...ng the ratio ...f a firm's total liabilities to total assets. The descriptive statisti...s of the main ...riables ...re listed in Table 1.

Table 1. Descriptive statistics of the main variables.

Variable	N	Mean	...d. Dev	...	Max
Dige	16,892	0.0316	0...76	0.002	0.9204
Res	16,892	0.0283	0.30...	−0.2540	1.8254
Hum	16,892	0.027...	0.0543	0.0020	0.9954
Inv	16,892	2.5...00	1.9101	0.0000	9.8709
Ww	16,892	...0032	0.1687	−1.6676	9.8843
IC	16,892	...6636	0.0868	0.0090	0.9915
Open	16,892	...3551	0.3278	0.0071	1.4110
Gdp	16,892	...5599	0.7...86	6.4159	11.6186
Inf	16,892	...65	...128	0.0513	2.1968
Size	16,892	7.7...	1.3394	1.7917	13.1397
Oper	16,...	0.3800	0.1840	0.0002	0.9870
Lnt	16,8...2	0.1528	0.1845	0.0001	1.0512
Lev	16,89...	...	0.2120	0.0050	0.6230

3.3. Data Sou...

...this pa...er, listed Ch...se A-share companies are taken as the research sample (A-share...amely RMB ordinary shares, are ordinary shares issued by companies registered ...China,...ted in Ch..., and denominated in RMB for domestic institutions, organizations, or individu... to subscribe and trade in RMB). The sample time span is from 2007 to 2020. The com...'s annual report text data from the official website of the Shanghai and ...enzhen Stock Exchanges required digital transformation variables and was manually re...med through Python. In the CSMAR and WIND economic and financial databases, the r...onal-level data were collected from the "China Statistical Yearbook" and the official websit... of the National Bureau of Statistics of China. Following the existing empirical research practice, the sample data are processed as follows. ① All of the financial industry ...amples are eliminated; ② the ST, PT, and insolvent samples are eliminated; ③ the samples with missing core explanatory variables are deleted. In addition, Winsorizing tailings were performed on all continuous variables at the 1% and 99% levels to mitigate the potential impact of outliers on empirical results. Finally, the observed values of 16,892 enterprise samples are obtained.

4. Results

4.1. Benchmark Regression

Table 2 lists the regression results of the impact of digital transformation on enterprise resilience. A progressive-regression strategy was adopted in this paper. Column (1) displays a regression result including only industry- and year-fixed effects. The regression coefficient of digital transformation on corporate resilience is significantly positive at the 1% confidence level, suggesting that digital transformation has significantly improved the corporate resilience of listed Chinese companies. Column (2) consists of the control variables at the enterprise and regional levels. The regression coefficient of digital transformation on

enterprise resilience is still significantly positive at the 1% confidence level. This further supports the conclusion that digital transformation can strengthen enterprise resilience. Therefore, our results imply that accelerating digital transformation is an essential method to enhance corporate resilience, and Hypothesis 1 was verified.

Table 2. Benchmark regression: digital transformation and enterprise resilience.

Variable	(1)	(2)
Dige	0.2527 ***	0.0229 ***
	(9.68)	(8.83)
Open		−0.0941 ***
		(−10.56)
Gdp		0.0460 ***
		(6.47)
Inf		0.0821 ***
		(3.61)
Size		0.0045 **
		(2.07)
Oper		0.0078 *
		(1.94)
Int		0.0126
		(0.37)
Lev		0.0282 ***
		(3.56)
Constant	0.0196 ***	−0.2589 ***
	(16.27)	(−4.35)
Year and Industry		YES
N	16,892	16,892
R-squared	0.0253	0.0317

Note: The t-statistic for the clustering firms is reported in parentheses; ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels, respectively. The same is below.

However, digital transformation, as a kind of change, may not always grow linearly but presents a nonlinear and irregular dynamic changes. Meanwhile, greater challenges are imposed to the existing organizational order and operating model, though digital transformation is conducive to improving corporate resilience.

From the perspective of control variables, provinces with higher levels of economic development and complete infrastructure are more conducive to the survival and development of enterprises at the regional level. These regions have stronger capabilities and resources to help enterprises handle shocks after adverse events occur. At the enterprise level, enterprises with a larger scale, higher operational efficiency, and higher debt ratio have stronger resource acquisition capabilities, can quickly perceive external changes, and make predictions for changes in the external environment to respond quickly. This helps mitigate the adverse effects of external shocks. The level of regional opening to the outside world has a negative inhibitory effect on the resilience of enterprises. The possible explanation is described as follows. First, with the change in the foreign market environment, the promotion effect of opening to the outside world is gradually weakening in promoting the development of Chinese enterprises, while the potential of the domestic market is being more deeply tapped. This also confirms the necessity of the strategy of "taking the domestic cycle as the main body, and the domestic and international dual cycles promoting each other," as established by China. Second, the higher the degree of opening up of a region to the outside world, the more vulnerable companies are to the impact of fluctuations in the international capital market. This deepens the external risk of the enterprise. The impact of intangible assets on an enterprise's resilience is not significant since many businesses have little or no intangible assets due to data reasons.

4.2. Robustness Check

4.2.1. Indicator Dimension Reduction

First, the digital transformation of enterprises is reflected in multiple dimensions. This study aimed to conduct a more in-depth discussion on the impact of digital transformation of enterprises on enterprise resilience and to verify the robustness of the basic conclusions of this paper. The five dimensions of digital transformation, including artificial intelligence (AI), blockchain (BD), cloud computing (CC), big data (DT), and digital technology application (ADT), were included in the measurement model to replace the original digital transformation variables of enterprises and re-examine the empirical test. The results are illustrated in column (1) of Table 3. The regression results demonstrate that the regression coefficient of cloud computing, big data, and digital technology applications on enterprise resilience is significantly positive at the 1% confidence level, implying that the higher the degree of enterprise application of cloud computing, big data, and digital technologies, the higher the enterprise resilience. Among them, big data has the most significant effect on improving enterprise resilience, and its coefficient is much larger than the coefficients of other digital transformation sub-indices; the application of artificial intelligence and blockchain has less of a significant impact on corporate resilience. The possible explanation is that, at present, artificial intelligence and blockchain are still in the early stages, and the technological maturity, independent innovation, scene fit, and completeness of institutional rules need to be further improved. At this time, its role in enhancing corporate resilience is not yet significant. Although the regression coefficients of artificial intelligence and blockchain variables are not significant, the data collected after the sub-dimension test implies that digital transformation can still improve the resilience of enterprises, and the core conclusions of this paper are still relatively stable.

4.2.2. Excluded Samples from Municipalities Directly under the Central Government

After considering the huge advantages of Chinese municipalities in terms of location and political economy, the samples from municipalities directly under the Central Government were eliminated, and the empirical test was performed again. The results are presented in column (2) of Table 3. The regression results unveil that the regression coefficient of digital transformation is still significantly positive at the 1% confidence level, and the core regression conclusion of this paper still maintains a high degree of robustness.

4.2.3. Add Industry and Year as Joint Fixed Effects

The joint fixed effects of year and industry were added to re-estimate the equation so as to alleviate the changes in the macroeconomic system, as listed in column (3) of Table 3. The regression results suggest that the regression coefficient of digital transformation on corporate resilience is significantly positive at the 1% confidence level, and the core regression results of this study are highly robust.

4.2.4. Endogenous Processing

There may be a two-way causal relationship between an enterprise's digital transformation and resilience. Enterprises with stronger resilience are more adaptable to the environment and are more willing and able to promote digital transformation and upgrading in the context of the digital economy era. This makes the judgment of causality in the empirical part of this paper face the problem of endogeneity. Additionally, the application of digitalization and related technologies in enterprises is not achieved overnight. It takes a certain amount of time for enterprises to promote digital transformation. The impact of digital transformation on enterprise resilience is gradual. Therefore, the digital transformation of the core explanatory variables was re-incorporated into the regression equation with one lag period and two lag periods for empirical testing in this paper. The results are presented in column (4) of Table 3, where it is revealed that whether the core explanatory variables lag one period or two periods, the regression coefficient of digital transformation on enterprise resilience is always significantly positive at the 1% confidence

level, and digital transformation can still improve enterprise resilience. Thus, the previous findings of our study remain robust. In sum, our results imply that digital transformation can still promote enterprise resilience, and the core conclusions of this paper are robust, as demonstrated by a series of robustness tests and endogenous processing.

Table 3. Results of the robustness test.

Variable	(1)	(2)	(3)	(4)	(5)
	Digital Transformation Sub-Dimension Test	Excluded Samples of Municipalities Directly under the Central Government	"Year × Industry" Fixed Effect	Variable Lag One Period	Variable Lag Two Periods
Dige		0.0301 ***	0.0523 ***	0.0908 *	0.0126 ***
		(2.77)	(3.86)	(3.22)	(2.97)
AI	0.0002				
	(1.28)				
BD	0.0009				
	(0.56)				
CC	0.0005 ***				
	(3.96)				
DT	0.0015 ***				
	(3.03)				
ADT	0.0008 ***				
	(8.71)				
Control	YES	YES	YES	YES	YES
Constant	−0.2726 ***	−0.1183	7.5728	−0.1182 ***	−0.0016 ***
	(−4.59)	(−3.63)	(13.44)	(−5.59)	(−4.09)
Year×Industry FE	NO	NO	YES	NO	NO
Year and Industry FE	YES	YES	YES	YES	YES
N	16892	13,252	16,892	11,565	9197
R-squared	0.0370	0.0188	0.0455	0.0145	0.0152

*** indicate significance at 1% confidence levels.

5. Heterogeneity Test

Due to the different endowments and regions of enterprises, the impact of digital transformation on enterprise resilience may also be heterogeneous. At the micro level, differences in corporate property rights and industry attributes will lead to differences in the economic consequences of digitization for companies. At the macro level, there is a "digital divide" between regions, which also affects the relationship between the two. Therefore, the impact of digital transformation on enterprise resilience is discussed from three aspects: enterprise property rights, enterprise industry attributes, and regions. First, the sample is divided into state-owned enterprises and non-state-owned enterprises, according to the property rights of enterprises. Second, the sample is divided into manufacturing and service industries following the industry attributes of enterprises. Finally, the sample is divided into the eastern, central, and western regions in accordance with where the enterprise is located.

5.1. Heterogeneity Group Test of Enterprise Property Rights Attributes

Columns (1) and (2) of Table 4 provide the results of grouping regression according to the property rights of enterprises. The results uncover that, among state-owned enterprises, the regression coefficient of digital transformation on corporate resilience is significantly positive at the 1% confidence level. However, the regression coefficient and statistical significance of non-state-owned enterprises were much lower compared to state-owned enterprises. Additionally, state-owned enterprises only passed the 5% statistical significance

test. Thus, our data imply that promoting digital transformation can significantly improve the resilience of state-owned and non-state-owned enterprises, but this improvement is more significant in state-owned enterprises. The possible reasons for the above conclusion are detailed as follows. First, compared with non-state-owned enterprises, state-owned enterprises have more abundant capital and technology and are more qualified and capable of implementing digital transformation; second, state-owned enterprises n[illegible]ume social and economic responsibilities and have stronger motivation an[illegible] willingne[illegible]o pursue digital transformation.

Table 4. Results of the heterogeneity test.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	State-Owned Enterprise	Non-State-Owned Enterprise	Manufacturing	Service Indu[illegible]	E[illegible]st	Midwest
Dige	0.4802 ***	0.0689 **	0.1566 ***	[illegible]0018	0.4[illegible] ***	−0.0071
	(5.04)	(2.21)	(7.14)	[illegible]0)	(4.[illegible]	(−1.40)
Control	YES	YES	YES	Y[illegible]	YES	YES
Constant	0.0018	−0.0847	−0.1440 ***	−0.0253 [illegible]	−0.8600 ***	−0.0473 ***
	(0.02)	(−1.39)	(−5.2[illegible]	(−17.79)	(−3.93)	(−9.66)
Year and Industry FE	YES	YES	Y[illegible]S	YES	YES	YES
N	6982	9910	10[illegible]78	591[illegible]	11,154	5738
R-squared	0.0555	0.0294	0.0[illegible]	0.1[illegible]86	0.0643	0.0719

***, ** indicate significance at 1%, 5% confi[illegible]levels[illegible]spectively.

5.2. Heterogeneity Group Test o[illegible]nterprise Industry Attributes

Columns (3) and (4) [illegible]f Table 4 illu[illegible]ate the results of the grouping regression according to the indust[illegible]y attributes [illegible]enterprises. The results demonstrate that in the manufacturing industr[illegible], the [illegible]gression c[illegible]efficient of digital transformation on enterprise resilience is signi[illegible]cantly p[illegible]sitive at the [illegible]% confidence level. In contrast, the regression coefficient of dig[illegible]l tran[illegible]formation on corporate resilience in the service industry is not significant. [illegible]ese re[illegible]lts indicate [illegible]at the digital transformation of the manufacturing industry has a significa[illegible]mprovement effect on corporate resilience, while this improvement effect has not yet be[illegible]shown for the service industry. The possible explanation is that digital [illegible]chnology ori[illegible]nates from the information and communication (ICT) industry, which is [illegible]re consistent with the manufacturing industry in nature and can be more deeply integ[illegible]ted with the manufacturing industry in the underlying technology, which may more e[illegible]ectively exert digital transformation's improvement on the resilience of enterprises. For the service industry, most companies rely on the workforce to provide various non-[illegible]tandardized and flexible, customized services. There are neither standards to refer to nor an experience or a future path to follow in digital transformation. As a result, the digitalization process of the service industry is slow, and it is difficult to play the role of digital transformation in improving the resilience of enterprises.

5.3. The Heterogeneity Group Test of the Region Where the Enterprise Is Located

Columns (5) and (6) of Table 4 list the results of the grouping regression based on the region where the company is located. Among enterprises in the eastern region, the regression coefficient of digital transformation on corporate resilience is significantly positive at the 1% confidence level. For enterprises in the central and western regions, the regression coefficient of digital transformation on corporate resilience has not passed the significance test. In other words, our data implies that digital transformation can improve the resilience of enterprises in the eastern region, while this effect is not captured in the enterprises in the central and western regions. Thus, there is a significant digital divide between the eastern, central, and western regions, which influences the digital transformation process of

enterprises to a certain extent. Compared with the central and western regions, the digital transformation of enterprises in the eastern region extends to a deeper level, and digital transformation may have a greater positive effect on corporate resilience.

6. Mechanism Identification Inspection

In this section, the channels through which digital transformation has [illegible] on enterprise resilience are discussed. With the intermediary variables of human capital, innovation capability, financing constraints, and internal control, the channel mechanism through which digital transformation affects enterprise resilience was tested according to the step-by-step test regression coefficient method proposed by Wen et al. [32].

6.1. The Mediating Effect Test of Human Capital

Columns (1), (2), and (3) of Table 5 demonstrate the test results of the mediation effect of human capital. The steps to test the mediation effect are designed as follows. First, the impact of digital transformation on corporate resilience is determined. The results suggest that digital transformation can significantly improve corporate resilience, and the next step can be tested. Secondly, the impact of digital transformation on human capital is judged. The results unveil that digital transformation can significantly improve the human capital level of enterprises, and this can be examined in the next step. Finally, the impact of digital transformation and human capital on enterprise resilience is explored. The results reveal that both digital transformation and human capital can significantly improve corporate resilience, implying that human capital is a critical mechanism for digital transformation to improve corporate resilience. The results of the mediation effect in the Sobel test reflect that the Z statistic of human capital is 5.9743, which passes the 1% statistical significance test. The mediation effect of human capital (0.0635 × 0.1441) accounts for 11.04% of the total effect (0.0829). Thus, Hypothesis 2 was verified. The test steps of the remaining variables' mediating effects are the same as the above process, and the specific steps will not be repeated.

Table 5. The impact mechanism of digital transformation on enterprise resilience (1).

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Res	Hum	Res	Res	Inv	Res
Dige	0.08[illegible]***	0.0635***	0.0720***	0.0829***	0.0623***	0.0700**
	(2.93)	(9.47)	(3.24)	(2.93)	(15.74)	(2.37)
Hum			0.1441***			
			(7.70)			
Inv						0.2839***
						(2.86)
Other variables	YES	YES	YES	YES	YES	YES
N	16,892	16,892	16,892	16,892	16,892	16,892
R-squared	0.0317	0.0692	0.0328	0.0317	0.0798	0.0328
Sobel test		Human Capital 5.9743*** The mechanism is effective —forward conduction			Creativity 2.8139*** The mechanism is effective —forward conduction	

Note: Other variables include industry, year-fixed effects, and control variables. ***, ** indicate significance at 1%, 5% confidence levels, respectively. The same is below.

6.2. The Mediating Effect Test of Innovation Ability

Columns (4), (5), and (6) of Table 5 report the results of the mediation effect test of innovation ability. The promotion of digital transformation of enterprises can significantly improve the innovation ability of enterprises, and digital transformation and innovation ability have a positive impact on enterprise resilience. This indicates that improving innovation capabilities is a critical mechanism for digital transformation to strengthen corporate resilience. The results of the mediation effect Sobel test reveal that the Z statistic of

innovation ability is 2.8139, which passes the 1% statistical significance test. The mediation effect of innovation ability (0.0623 × 0.0700) accounts for 5.26% of the total effect (0.0829). Hence, Hypothesis 3 was verified.

6.3. The Mediating Effect Test of Financing Constraints

Columns (1), (2), and (3) of Table 6 present the results of the mediation effect test of financing constraints. The results demonstrate that the digital transformation of enterprises can significantly ease corporate financing constraints, and digital transformation and financing constraints can enhance corporate resilience. In other words, alleviating financing constraints is an imperative mechanism for digital transformation to enhance corporate resilience. The results of the mediation effect Sobel test suggest that the Z statistic of financing constraints is 2.6568, which passes the 1% statistical significance test. The mediation effect of financing constraints (0.1486 × 0.0642) accounts for 11.51% of the total effect (0.0829). Therefore, Hypothesis 4 was verified.

Table 6. The impact mechanism of digital transformation on enterprise resilience (2).

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Res	Ww	Res	Res	Ic	Res
Dige	0.0829 *** (2.93)	0.1486 *** (4.05)	0.0564 *** (10.39)	0.0829 *** (2.93)	0.3521 *** (6.57)	0.0801 *** (2.99)
Ww			0.0642 *** (3.52)			
Ic						0.0079 *** (4.78)
Other variables	YES	YES	YES	YES	YES	YES
N	16,892	16,892	16,892	16,892	16,892	16,892
R-squared	0.0317	0.0951	0.0796	0.0317	0.1394	0.0317
Sobel test	Financing Constraints 2.6568 *** The mechanism is effective —forward conduction				Internal Control 3.8652 *** The mechanism is effective —forward conduction	

*** Indicate significance at 1% confidence levels.

6.4. The Mediation Effect Test of Internal Control

Columns (4), (5), and (6) of Table 6 offer the results of the mediation effect test of internal control. The promotion of digital transformation of enterprises can significantly strengthen the internal control of enterprises, and digital transformation and internal control have a positive impact on enterprise resilience. This demonstrates that strengthening internal control is an essential mechanism for digital transformation to improve corporate resilience. The results of the mediation effect Sobel test unveil that the Z statistic of internal control is 3.8652, which passes the 1% statistical significance test. The mediation effect of internal control (0.3521 × 0.0079) accounts for 3.36% of the total effect (0.0829). Hence, Hypothesis 5 was verified.

7. Conclusions and Implications

7.1. Research Conclusions

Digital transformation has critical strategic significance for improving corporate resilience in effectively responding to external shocks and achieving sustainable development. In this paper, the internal mechanism of digital transformation to promote enterprise resilience is first discussed theoretically. Then, the text analysis and entropy weight TOPSIS methods were combined to characterize the digital transformation intensity of enterprises. On this basis, the impact of digital transformation on enterprise resilience was empirically tested. The impact of digital transformation on corporate resilience, its mechanism of action, and heterogeneity were investigated in this study to lay an empirical foundation for the research on the economic effects of the integration of big data and physical enterprises.

Our study reveals that the digital transformation of enterprises can significantly enhance their resilience. This conclusion remains after a series of robustness tests and endogenous processings. Additionally, a heterogeneity analysis suggested that digital transformation can improve the resilience of SOEs and non-SOEs, but this improvement was more pronounced in SOEs. Regardless of the significant positive effect of digital transformation on manufacturing and enterprises in the eastern region, this effect was not observed in the service industry and enterprises in the central and western regions. Concerning the mechanism of action, our data suggests that digital transformation can improve corporate resilience by improving the level of human capital, enhancing innovation capabilities, easing credit constraints, and strengthening internal control.

7.2. Policy Implications

The research conclusions of this paper suggest that digital transformation can effectively improve corporate resilience. The following policy recommendations are proposed to give full play to the role of digital transformation in enhancing corporate resilience.

(1) For the government, it is necessary to support the digital transformation of enterprises vigorously. First, the government should focus on the difficulties and pain points in the process of digital transformation of enterprises while cultivating a group of digital transformation application scenarios with strong comprehensiveness and wide driving range by selecting a group of highly scalable digital transformation solutions, establishing a group of industry-representative digital transformation benchmarking companies, and actively exploring new paths for digital transformation. Second, the government should make good use of an online teaching platform to perform digital transformation training for enterprises, guide enterprises in strengthening their digital thinking, and improve the digital insight and skills of the enterprise's management and employees. Additionally, the digital transformation of small- and medium-sized enterprises is relatively deficient in advantages. Policy and taxation should be tilted towards small- and medium-sized enterprises, reduce the technical and financial barriers of small- and medium-sized enterprises, and accelerate the digital transformation of small- and medium-sized enterprises. Finally, the government should guide internet-leading enterprises to use their own advantages actively, build open and digitalizable platforms, provide comprehensive and integrated intelligent information services, and help traditional and small- and medium-sized enterprises promote the implementation of industrial digital transformation strategies.

(2) For enterprises, it is necessary to accelerate the process of digital transformation. Given the different effects of digital transformation on enterprises with different attributes, enterprises must build a digital transformation plan that meets their own goals and characteristics following their actual conditions. Enterprises should use cloud computing, big data, artificial intelligence, blockchain, Internet of Things, 5G, and other emerging digital technologies to promote the optimization of production, operation, and management models, industrial chain collaboration, information structure, concept innovation, as well as promote the digital transformation to a deeper level, and thus effectively enhance the ability of enterprises to resist risks. In the process of promoting the large-scale application of digital technology, enterprises must abide by the relevant laws and regulations of the state and grasp the reasonable-use boundaries of digital technology while actively performing social responsibilities, cooperating with the relevant requirements of the government's digital governance, and mitigating data risks brought about by digital transformation.

(3) At present, the digital transformation of enterprises is in the initial stage of exploration as a whole, and there are relatively high risks. More state-owned enterprises are gradually shifting from purely pursuing economic benefits to building digital enterprises and ecology and actively shouldering higher social responsibilities. Its digital transformation experience can provide a reference for other companies in the industry. This reflects the advantages of the socialist market economic system with

Chinese characteristics. Simultaneously, state-owned enterprises are also the core links of China's industrial and supply chains. Promoting the digital transformation of state-owned enterprises can enhance our country's position in the global industrial supply chain value. This suggests that governments at all levels and relevant functional departments should actively cooperate with state-owned enterprises, as well as make state-owned enterprises a model of enterprise digitalization, which effectively gives way to the demonstration and leading role of state-owned enterprises to cooperate and promote the process of regional digital transformation.

(4) The existence of the regional "digital divide" is not conducive to the promotion of digital transformation of enterprises, and it must be quickly shortened. This requires the coordinated efforts of the eastern, central, and western regions.

Concerning the eastern region, the development advantages and driving role of the digital economy should be strengthened, and the demonstration role of building the digital economy should continue to be well-played. The eastern region should maximize its advantages in innovation, industry, location, and resources, as well as accelerate the introduction of key production factors such as digital talents and technologies, and form a digital economy development model with its own characteristics so as to build a model for the development of the national digital economy.

Regarding the central region, the digital economy should be fully performed in promoting industrial transformation and upgrading the modernization level of the industrial and supply chains. Then, the central region's "four bases and one hub" will be further consolidated—that is, the bases of grain production, energy and raw materials, modern equipment manufacturing, high-tech industrial, and an integrated transportation hub.

With respect to the western region, it is necessary to establish and improve the digital economy planning, support the policy system as soon as possible and build a digital ecological environment suitable for the development of the digital economy. The historic opportunity of industrial transfer in the eastern region should be seized. Additionally, more advanced digital economy enterprises and projects need to be vigorously introduced, and the digital transformation of local enterprises and industries is expected to be promoted. Moreover, the resource advantages of the western region (such as the temperature to meet the cooling demands and cheap land prices) must be fully utilized to build a big data service center serving the whole country.

7.3. Research Deficiencies and Prospects

Although machine learning and text analysis methods are employed in this paper to measure the overall situation of the digital transformation of enterprises, the degree of digital transformation of internal production, operations, and other processes has not been better measured. Specific details such as input and speed of digital transformation should be better described. Future research will improve the measurements involving the degree of digital transformation so as to understand its impact on corporate decision-making and economic consequences more deeply.

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Appendix A

The calculation formula of the entropy weight TOPSIS method is detailed as follows:

Step 1: Determine the target sequence and perform dimensionless processing on the data. The processing methods of the positive and negative indicators are:

$$x_{ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})} \quad (A1)$$

$$x_{ij} = \frac{\max(X_{ij}) - X_{ij}}{\max(X_{ij}) - \min(X_{ij})} \quad (A2)$$

where X_{ij} denotes the initialization value of the i-th object of the j-th indicator; x_{ij} represents the standardized value of the i-th object of the j-th indicator, i is the number of indicators, $i = 1, 2, \ldots, m$; j is the number of objects number, $j = 1, 2, \ldots, n$. The standardized matrix is obtained after calculation by formula A:

$$A = \begin{bmatrix} x_{11} & \cdots & \\ \vdots & & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (A3)$$

Step 2: Calculate the weight using the entropy weight TOPSIS method:

$$w_i = \frac{1 - e_i}{m - \sum_{i=1}^{m} e_i} \quad (A4)$$

$$f_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad (A5)$$

where w_i indicates the index weight, and e_i refers to the information entropy. If f_{ij}=0, then $\lim_{x \to 0} f_{ij} \ln f_{ij} = 0$. In the entropy weight calculation, if f_{ij} is 0 and the logarithm calculation cannot be performed, then the mean difference method is used. Then, the logarithm calculation is performed after adding 1 to it.

Step 3: Construct the TOPSIS model. The matrix Y is created according to the weight w_i, as determined by the entropy weight TOPSIS method:

$$Y = \left|\gamma_{ij}\right|_{m \times n} = \left|w_i \times x_{ij}\right|_{m \times n} \quad (A6)$$

Step 4: Determine the positive- and negative-ideal solutions. The positive-ideal solution, c, is the optimal solution of each index, which is the maximum value of the i-th index in the evaluation data in the j-th object. The negative-ideal index Y^- indicatesthe worst solution of each index, which is the minimum value of the i-th index in the j-th object in the evaluation index number. The specific calculation formula is:

$$Y^+ = max\{\gamma_{ij}\} \quad (A7)$$

$$Y^- = \min\{\gamma_{ij}\} \quad (A8)$$

Step 5: Calculate the Euclidean distance between each scheme and the positive- and negative-ideal solutions. Let D_j^+ denote the distance between the i-th index and y_i^+, and D_j^- denote the distance between the i-th index and y_i^-. The specific calculation formula is:

$$D_j^+ = \sqrt{\sum_{i=1}^{m} (y_i^+ - \gamma_{ij})^2} \quad \text{(A9)}$$

$$D_j^- = \sqrt{\sum_{i=1}^{m} (y_i^- - \gamma_{ij})^2} \quad \text{(A10)}$$

Step 6: Calculate the comprehensive evaluation index of each scheme. C_j is the digital transformation degree of the c-th enterprise, and the value range is [0, 1]. Specifically, C_j closer to 0 suggests a lower degree of digital transformation, and closer to 1 implies a higher degree of digital transformation. The specific calculation formula is:

$$C_j = \frac{D_j^-}{D_j^+ + D_j^-} \quad \text{(A11)}$$

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