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Study on the Impact and Mechanism of Industrial Internet Pilot on Digital Transformation of Manufacturing Enterprises

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Abstract: In the era of digital economy, Industrial Internet is promoting the deep integration of manufacturing industry and the Internet through the new generation of information technology, which has become a new driving force to encourage the development of digital transformation of manufacturing enterprises. In this paper, we use the China Industrial Internet Pilot Demonstration Project as a proposed natural experiment to assess the impact and mechanism of action of the Industrial Internet pilot on the digital transformation of manufacturing enterprises using score propensity matching and double-difference methods based on panel data of annual reports of manufacturing listed companies from 2012 to 2020. The empirical results show that the Industrial Internet has a significant empowering effect on the digital transformation of manufacturing enterprises and positively promotes the digital transformation of manufacturing enterprises through the mechanism of digitalization, technology absorption, talent introduction, and innovation integration of industry cohort enterprises; the heterogeneity analysis shows that the empowering effect of the Industrial Internet is more substantial for technology-intensive enterprises, diversified business enterprises, and enterprises in the eastern region. This study provides empirical evidence for understanding the digital transformation of manufacturing enterprises enabled by the Industrial Internet. It provides theoretical support for promoting the development of Industrial Internet projects and achieving sustainable development of the manufacturing industry.

Keywords: Industrial Internet; digital transformation; transformation mechanisms; propensity score matching; double differencing

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1. Introduction

Global manufacturing and trade activities have been affected by the energy crisis, the epidemic of the century, and the uncertainty of economic development, which have accelerated the global industrial chain adjustment and supply chain restructuring, and the development of the real economy, mainly manufacturing, has regained the focus of international economic competition. The global factor pattern shows the transformation trends of digital substitution, interconnection enhancement, diversified embedding, and multidimensional dependence. The transformation of the manufacturing industry to digitalization has become a pivotal opportunity to improve the quality of actual economic development [1]. The manufacturing industry is the foundation of China. It plays a positive role in promoting the development of national economy and supply chain innovation. Still, it is also faced with transformation difficulties such as lagging information development, industrial structure limitation, core technology "neck", and product homogenization, which restrict China's manufacturing industry's competitiveness and development potential [2]. The manufacturing industry in developed countries has moved through the stages of automation, lean and flexible manufacturing to realize the transformation from large-scale manufacturing to intelligent manufacturing, and its progressive development history and experience show that accelerating the deep integration of informatization and industrialization to the development of intelligence, informatization, and digitalization is the key to realizing the transformation and upgrading of the manufacturing system.

Under the historical intersection of industrial informatization expansion and Internet extension to production, a new infrastructure, application model, and industrial ecology that can fully interconnect people, machines, and things—Industrial Internet—has been rapidly developed. By optimizing the allocation of production factors and resource integration, the Industrial Internet improves the efficiency of the industrial chain and realizes the upgrade of the industrial chain, showing a new development vitality in the process of manufacturing transformation. Germany regards the Industrial Internet as an essential carrier of "Industry 4.0", and the United States believes it is a necessary foundation of the "Advanced Manufacturing Partnership" and "Re-industrialization Strategy". The Industrial Internet is also an essential engine for China to promote the "Made in China 2025" manufacturing power strategy and an inevitable choice for Chinese enterprises to transform into a fully connected development. The process integration of human–machine interaction, physical objects in production lines, and intelligent machines helps develop efficient industry value chains. Manufacturing companies use digital technology to create new business models with different capabilities, thus enhancing their core competitiveness [3]. In practice, manufacturing enterprises have gradually stepped from the wait-and-see stage of digital transformation to the landing stage, and in the face of the multiple forms of Industrial Internet applications, the differences in their situations and the different environments they are in make it difficult to replicate successful experiences among enterprises in various fields quickly. Since 2018, the Ministry of Industry and Information Technology of China has launched the Industrial Internet pilot demonstration project to actively promote the application of the Industrial Internet by Chinese enterprises through piloting first and demonstration leading the way. The Industrial Internet has become a pivotal grip to promote the transformation and upgrading of the manufacturing industry and an objective requirement for sustainable development. It is of theoretical and practical significance to study the impact of the Industrial Internet on the digital transformation of manufacturing enterprises and clarify the intrinsic impact mechanism to continuously promote the development of the Industrial Internet.

In a series of studies on the Industrial Internet in China, it is pointed out that the Industrial Internet is the role form of industrial interconnection that exists in most traditional manufacturing enterprises at this stage. As an emerging concept in the industrial field, the Industrial Internet has received extensive attention from industry and academia. Initially, related research has been carried out mainly in terms of theoretical construction and algorithmic implementation based on the perspective of industrial interconnection. Theoretically, it explores the connotation of the era of industrial interconnection development and intelligent interconnection thinking [4], industrial interconnection platform synergy and program design [5], and focuses on Industrial Internet platform construction and evaluation [6]; in the form of technical implementation, it explores industrial interconnection synergy recommendation and system models [7], industrial interconnection synergy planning and scheduling [8], etc. With the depth of Industrial Internet policies, the research focuses on the enabling role of industrial policies and economic after-effects. Based on the exploration of text mining evolution [9] and quantitative evaluation [10] of industrial policies, scholars further delve into the impact of Industrial Internet policies on enterprises' R&D investment [11] and digital transformation [12] based on policy perspectives. Regarding enterprise applications, the study focuses on the impact of manufacturing enterprises on the Industrial Internet to promote digital innovation [13], value creation [14], and industrial upgrading [15].

Meanwhile, with regard to digital transformation, the macro level focuses on the digital economy [16] and its measurement [17], including digital industrialization and industrial digitization, the economic effect [18], mechanism of digital empowerment [19] of China's industrial high quality, etc. The micro level mainly concentrates on the research of enterprise Internet capability, the effect on enterprise innovation and performance enhancement, enterprise strategic management change, the realization and upgrading path of enterprise digital transformation, etc. Some scholars have also initially constructed the connotation framework of digital transformation through a large number of case explorations and theoretical studies, focusing on the application of digital technologies such as the Internet of Things and platform ecology acting on data availability, customer demand, and competitive landscape, further triggering the adjustment of digital enterprise strategies. The micro level mainly focuses on enterprise Internet capability [20], the effect on enterprise innovation [21] and performance enhancement [22], enterprise strategic management change [23] and enterprise digital transformation, the realization and upgrading path of digital transformation [24], etc. Some scholars have also tentatively constructed the connotation framework of digital transformation through numerous case explorations and theoretical studies [25], focusing on the application of digital technologies such as the Internet of Things and platform ecology acting on data availability, customer demand, and competitive landscape, and further triggering the adjustment of enterprises' digital strategies.

The above literature provides a theoretical basis and research perspective for an in-depth exploration of the impact mechanism of the Industrial Internet on the digital transformation of enterprises. The review found that existing studies have focused on the theoretical analysis of the overall implementation model of the Industrial Internet, and the development advantages of the Industrial Internet have been extensively explored, mainly at the contextual level and policy-driven, in the portrayal of the Industrial Internet. Studies have verified the driving influence of the Industrial Internet on digitization. Still, there needs to be more verification and mechanism exploration of how factors act on digital transformation from the perspective of the Industrial Internet. The China Industry 4.0 Institute points out that the Industrial Internet presents specific challenges regarding pilot demonstrations, with little literature examining the Industrial Internet from the perspective of pilot projects. At the same time, the Industrial Internet pilot annual demonstration project provides the research conditions for this paper to launch a proposed natural experiment on the Industrial Internet. Therefore, this paper treats the national Industrial Internet pilot demonstration project as a proposed natural experiment and explores the impact mechanism and heterogeneity of Industrial Internet on the digital transformation of manufacturing enterprises from the perspective of a multiply mediated empowerment.

This study's main contributions are as follows: (1) This study enriches the driving perspective of enterprise digital transformation. From the micro-enterprise perspective, the manufacturing enterprises corresponding to the Industrial Internet demonstration pilot projects announced by the National Industry and Information Technology Department are collated. The impact of Industrial Internet pilots on enterprise digitalization is explored using a double difference and propensity score matching model. (2) This study expands the multiple sustainable empowerment mechanisms of the Industrial Internet on the digital transformation of enterprises, using the cohort effect, technology absorption, talent introduction, and innovation integration as mediators. (3) This study analyzes the enterprise, industry, and regional heterogeneity of Industrial-Internet-enabled enterprise digitization. It further enriches the research perspective of the Industrial Internet and provides new thinking directions and suggestions for manufacturing industries to realize transformation.

2. Literature Review and Research Hypothesis

2.1. Literature Review

The Industrial Internet is the application of Internet of Things (IoT) technology in the manufacturing industry [26], which aims to complete the transformation of processes and equipment in the manufacturing value chain to intelligent and smart production methods [27], combining machine learning and big data technologies, sensor data, and machine-to-machine (M2M) communication that have existed in the industrial industry for many years, which can achieve effective resource integration to improve productivity, production efficiency, and production reliability in manufacturing companies [28]. The US Industrial Internet Consortium (IIC) has proposed an Industrial Internet architecture containing an enterprise layer, an edge layer, and a platform layer from the technical application level. China's Industrial Internet Industry Alliance (All) defines the Industrial Internet as an emerging industry and application model formed by the full and deep integration of a new generation of information technology, industrial systems, and the Internet. It is a crucial integrated information infrastructure for the development of intelligent industries. As pointed out in the Ariadne Consulting Industrial Internet series of studies, the Maas model (production as a service) of industrial manufacturing in China based on industrial interconnection first emerged in 2014, with service providers such as Business Help and Cloud Factory mainly serving light, discrete manufacturing industries such as small- and medium-batch 3D printing, small machinery, and parts processing. In heavy discrete manufacturing industries with high industry concentration, relatively stable demand fluctuations, production capacity, and process manufacturing industries where manufacturing and processing processes are not detachable, industrial interconnection still remains at the stage of information connectivity represented by the Industrial Internet [29].

In terms of research on enterprise applications of the Industrial Internet, some studies have focused on development measurement and effect evaluation. Lv [30] measured the development level of Industrial Internet platforms in 30 Chinese provinces and cities through three significant aspects: platform infrastructure, information industry development level, and enterprise intelligence level, and empirically investigated the effects and mechanisms of the Industrial Internet in promoting the upgrading of the manufacturing industry by facilitating structural upgrading and production efficiency improvement at the macro level. Shi [31] measured the level of Industrial Internet development at the provincial level through three dimensions: platform infrastructure, platform economic development level, and platform core products, using the comprehensive index method. From the perspective of the overall development of the Industrial Internet, Guo [15] measured the development of the Industrial Internet at the provincial level in China by constructing the Industrial Internet development level index system based on the Internet embedding degree, and Zhao [32] measured the basic level of regional Industrial Internet development and application with the measurement index of the White Paper on Industrial Internet Development and Application Index, and studied the Industrial Internet in China based on the implementation cases in each province implementation capability, pointing out the significant impact of technical conditions on the improvement of Industrial Internet implementation capability. From the perspective of enterprise application of the Industrial Internet, Dou [33] portrayed the Industrial Internet variables through the degree of Internet application of enterprises and studied its contribution to the servitization of manufacturing to enhance enterprises' global value chain. Wang [34] extracted keywords from enterprises' annual reports to confirm the project situation of Industrial Internet to measure whether enterprises apply Industrial Internet, and quantitatively studied the impact of Industrial Internet on enterprises' digital innovation, pointing out that the effect on the innovation input side is more significant than that on the innovation output side. Zhao [35] studied the mechanism of the role of the ecological embedding of the Industrial Internet platform on the exploratory innovation performance of the participating enterprises by investigating the enterprises applying COSMOPlat and Langchao cloud platform ecology.

In the current phase of emerging technologies, some scholars have focused on how the Industrial Internet can empower manufacturing and the impact on the digital transformation of manufacturing companies. Digital transformation is a process that aims to improve entities by triggering significant changes in their attributes through the developmental convergence of information, computing, communication, and connectivity technologies, where organizations transform their value creation processes through the use of digital technologies to respond to the changes taking place in their environment. At the organizational level, Hess [36] argues that companies innovate with these technologies by designing strategies that embrace the implications of digital transformation and drive better operational performance. At the industry–industry system level, Majchrzak [37] argued that digital transformation encompasses the profound changes that occur in society and industry through the use of digital technologies. Based on the case of Haier Group's smart manufacturing platform, Lu [38] provided an in-depth analysis of Chinese enterprises' smart manufacturing implementation models and enterprise platform construction processes and governance systems, and the study demonstrated that the Industrial Internet has empowered Haier's smart manufacturing implementation effect significantly. Cai [39] pointed out that the model of the Industrial Internet using digital technology to promote the development of the manufacturing industry is well suited to the upgrading of China's manufacturing industry. In the logic of the Industrial Internet's empowerment of the manufacturing industry, the first step can be to promote the digital transformation of enterprise production through the introduction of the Industrial Internet, specifically through the data of the production process, to achieve technological innovation in production within the enterprise, thereby improving the production efficiency of the enterprise. Guo [15] studied the impact of the level of Industrial Internet development on the upgrading of China's manufacturing industry and the underlying mechanisms, and argued that Industrial Internet development significantly contributes to the upgrading of the manufacturing industry, while the Industrial Internet can indirectly promote the upgrading of the manufacturing industry through innovation and human capital accumulation. Tang [40] argued that the application of the Industrial Internet can effectively enhance the service value creation capability of the manufacturing industry, promote cross-sector value creation, and reshape the service-oriented value creation system of the manufacturing industry. Thus, the Industrial Internet can realize talent and technology elements gathering but also can organically integrate cross-chain value, thus realizing technological innovation and service value cocreation, forming an industrial interconnection ecosystem resource circulation, intensely promoting the digital transformation of manufacturing enterprises and reducing costs and increasing the efficiency with intelligent manufacturing, becoming an excellent way for enterprises to seek sustainable development and achieve a win–win situation.

2.2. Research Hypothesis

2.2.1. Industrial Internet and Enterprise Digital Transformation

Digital transformation is the reshaping of business processes, organizational structures, and business cooperation models through the deep integration of various information technology and business sectors, thus helping enterprises to create and obtain more value [41]. In the process of integrating information technology, advanced technology, and manufacturing equipment facilities, the main breakthrough in the transformation of intelligent manufacturing lies in large manufacturing enterprises and Industrial Internet platforms that are on the supply side. In terms of the core technologies of the Industrial Internet, open IoT operating systems and cloud computing SaaS platforms integrate an enterprise's hardware equipment, software management systems, and digital application PaaS cloud services into an organic whole, providing traditional manufacturing enterprises with a closed-loop solution for the whole process of their core business to achieve value creation and, ultimately, digital transformation. It has also been pointed out that positive policy and environmental orientations also influence, to some extent, the degree of attention manufacturing enterprises pay to digital transformation, and some empirical studies have shown that China's digital economy policies will increase the willingness of enterprises to digital change [42]. In recent years' practice, the Haier COSMOPlat smart manufacturing and Industrial Internet platform has provided a boost to the digital transformation of small and medium-sized manufacturing enterprises, and many manufacturing giants have also realized the transformation to service-oriented manufacturing, providing a full set of solutions with the help of Industrial Internet. Therefore, we propose the following hypothesis:

H1. *The Industrial Internet facilitates the digital transformation of manufacturing enterprises.*

2.2.2. Digital Cohort Effect Empowerment

The Industrial Internet integrates information in areas such as industrial data, which can be better utilized by enterprises through interenterprise cooperation to achieve optimization of production processes and link patterns by facilitating industry chain integration. Within the same industry domain, the Industrial Internet acts as a capability delivery pipeline. It can provide industrial software, related manufacturing resources, and industry knowledge to peer enterprises [43], playing a role in enhancing the synergistic improvement of digital capabilities in the same industry. Regarding industrial interconnection, the Industrial Internet aggregates and deposits digital production materials in the cloud, accelerating the penetration and diffusion of industry knowledge and digital technologies upstream and downstream in the industrial chain [44]. Under this mechanism, interindustry digital learning and imitation behaviors further influence enterprises' digital transformation decisions and behavioral changes and enhance the effectiveness of digital transformation [45]. The synergistic diffusion mechanism of digitalization in the same industry benefits from the digital element linking method of the Industrial Internet [46]. Based on the above analysis, the following hypotheses are proposed:

H2. *The Industrial Internet empowers enterprises' digital transformation through the digital cohort effect*.

2.2.3. Talent Introduction Effect Empowerment

In the fully connected intelligent manufacturing model, the transformation of enterprises in production, design, service, and operation and maintenance requires comprehensive skilled talents in multiple fields. On the one hand, emerging technologies bring enterprises a larger scale and higher standard of talent demand. The supply gap and structural imbalance of Industrial Internet talents have prompted enterprises to improve the quantity and quality of talent supply [47]. On the other hand, the development of various platforms, such as the Industrial Internet, has driven digital employment, showing the talent attraction effect of digital employment space [48]. Enterprises oriented to the new mode of industrial interconnection can attract more digitally literate talents. In terms of digital talent demand and employment attractiveness, the Industrial Internet has played a beneficial role in introducing talent to enterprises. A team of highly qualified and specialized skills can provide more comprehensive and advanced solutions to help enterprises better manage and promote the informatization process. Based on the above analysis, the following hypotheses are proposed:

H3. *The Industrial Internet empowers the digital transformation of enterprises by promoting the effect of talent introduction*.

2.2.4. Technology Absorption Effect Empowerment

Enterprise technology absorption uses the Internet platform to combine the enterprise's R&D achievements with market demand and to promote product innovation and development through market feedback. The Industrial Internet can provide more data sources for enterprises. Manufacturing enterprises are empowered by the massive amount of information and application interfaces collected by the Industrial Internet platform [49]. Companies can develop new products, optimize existing business processes and improve quality management methods more flexibly, enhance their digital analysis and processing capabilities, and further effectively use Industrial Internet technologies, product innovation, and R&D platforms. At the same time, the Industrial Internet can help enterprises achieve real-time mastery and monitoring of market information, production processes, and other aspects through technology, providing them with more rapid, convenient, and effective means of decision support. Manufacturing enterprises need to digest and convert the data resources of the Industrial Internet platform to apply them to business activities [50]. It can be assumed that enterprise technology absorption helps enterprises to organically integrate the Industrial Internet with their own business and achieve digital transformation through a series of transformation and adaptation processes. Based on the above analysis, the following hypothesis is proposed:

H4. *The Industrial Internet empowers the digital transformation of enterprises by facilitating their technology uptake.*

2.2.5. Innovation Integration Effect Empowerment

The essence of digital transformation is using digital technology to drive the innovation and renewal transformation of enterprise development models. The quality of invention is related to the high-quality transformation development of enterprises. In the internal and external environment of the organization, practical use and integration of heterogeneous resources to achieve cross-domain innovation is an effective way to enhance the quality of enterprise innovation. The Industrial Internet mainly promotes enterprises to integrate innovation resources through the advantages of industrial interconnection and resource acquisition. On the one hand, the Industrial Internet brings the interconnection distance and degree of association between industries closer, promoting the free combination and matching of resources from heterogeneous industrial sources and enhancing enterprises' rapid integration ability for target resources [51]. On the other hand, the Industrial Internet relies on the advantages of aggregation and interconnection sharing of multiple resources to weaken the information asymmetry between supply and demand, and enterprises can effectively grasp the data resources and processes in production operations, improving the efficiency and convenience of enterprises' access to heterogeneous information. Enterprises embedded in the Industrial Internet platform ecosystem can absorb broader and diversified technical knowledge through searching, matching, and integrating cross-domain resources, speeding up digital interconnection technology development and implementation, and supporting the digital transformation of enterprises. Based on the above analysis, the following hypotheses are proposed:

H5. *The Industrial Internet empowers enterprises' digital transformation by promoting enterprise innovation integration.*

3. Study Design

3.1. Method Selection and Model Setting

In order to explore the driving effect of the Industrial Internet on the digital transformation of enterprises and to scientifically evaluate the effect of the Industrial Internet before and after its implementation, this paper considers the Industrial Internet pilot demonstration projects selected by the State Ministry of Industry and Information Technology from 2018–2020 as quasi-natural experiments, aiming to answer how the level of digital transformation of manufacturing enterprises will change with the implementation of the Industrial Internet pilot. If the level of digital transformation of manufacturing enterprises in both states of implementation and nonimplementation of industrial interconnection can be observed simultaneously, the causal disposition effect of the Industrial Internet pilot is the difference between the two. However, due to the selective bias problem that the initial conditions of selected and nonselected enterprises are not identical, in reality, only one actual state of manufacturing enterprises before and after being selected for the Industrial Internet pilot demonstration project can be observed, and a counterfactual analysis framework needs to be constructed to identify the results. Using manufacturing enterprises selected for the Industrial Internet pilot demonstration project as the treatment group and manufacturing enterprises not selected for the Industrial Internet pilot as the control group, it is assumed that the two groups of enterprises have the same temporal development trend before the Industrial Internet pilot, and the digital development of enterprises after being selected for the Industrial Internet pilot project has been affected. The propensity matching score method is used to solve the problem of selection bias of the sample and direct comparability. The problem of small sample size and the endogeneity of omitted variables are addressed by using the double check score method. Due to the different timing of access to the pilot demonstration projects by different enterprises, a multitemporal fixed effects double difference model was constructed as follows:

$$DT_{i,t} = \beta_0 + \beta_1 treat_{i,t} + \gamma \sum controls_{i,t} + FirmFE + ProvinceFE + IndustryFE + YearFE + \varepsilon_{i,t}$$

where i represents manufacturing firms and t represents the year. The explanatory variable $DT_{i,t}$ denotes the level of digital transformation of manufacturing firms, and $treat_{i,t}$ denotes the dummy variable for manufacturing enterprises' industrial interconnection-oriented projects. When enterprise i undergoes industrial interconnection in year t, the year it is approved and subsequent years are $treat_{i,t}$. The Ministry of Industry and Information Technology (MIIT) stipulates that enterprises must meet the basic elementary conditions, conform to the direction of Industrial Internet innovation and development, and have significant driving effect and application effectiveness to declare Industrial Internet pilot demonstration projects. Coefficient β_1 reflects the impact effect of industrial interconnection on the digital transformation of enterprises; if β_1 is positive, it means that industrial interconnection plays a driving role in the digital transformation of enterprises. $controls_{i,t}$ denotes a set of control variables that also serve as covariates reflecting individual characteristics when propensity score matching is conducted. *FirmFE*, *ProvinceFE*, *IndustryFE*, and *YearFE* denote firm, province, industry, and year fixed effects, respectively. $\varepsilon_{i,t}$ denotes a random disturbance term.

3.2. Selection of Variables

3.2.1. Explanatory Variables

The explanatory variable is the level of enterprise digital transformation DT. In the white paper on enterprise digital transformation jointly published by Huawei and IDC, it is pointed out that the ratio of industry ICT investment to business revenue is one of the elements affecting the maturity of enterprise digital transformation [52]. Accordingly, this paper uses the proportion of enterprise information technology investment to primary business revenue as an indicator of the level of enterprise digital investment. Referring to the research practice of Wang [53], enterprise information technology investment is divided into two parts: IT hardware investment and IT software investment. The year-end book value of items such as electronic and communication equipment in the fixed asset details of the enterprise's annual report is taken as the hardware part of enterprise digital investment, and the year-end book value of items such as computer technology software, office software, and management and application systems in the intangible asset details is taken as the software component.

3.2.2. Explanatory Variables

The explanatory variable is the Industrial Internet pilot, using a double difference term $treat_{i,t}$ measure. Treat takes the value of 1 if the company is selected as an Industrial Internet pilot demonstration project in the current year; otherwise, it takes the value of 0.

3.2.3. Control Variables

The selection of control variables affects the quality of matching between the control and control groups in the propensity matching score estimation. In this paper, the following control variables are selected with reference to relevant studies: firm size (Size), profitability (ROA), debt capacity (LEV), growth (Growth), proportion of fixed assets (Fixed), and board size (Board). The variables are defined in Table 1.

Table 1. Definition of variables.

Variables	Variable Name	Variable Symbols	Variable Description
Explained variables	Level of digital transformation of enterprises	DT1 DT2	Ln [1+ (investment in information technology hardware + investment in information technology software)/main business revenue]. Ln (number of keywords characterizing digital transformation in the annual report + 1).
Explanatory variables	Industrial interconnection pilot companies	$treat_{i,t}$	A value of 1 is assigned to the pilot demonstration projects selected for the Industrial Internet in the current year, and 0 to the opposite.
Control variables	Size of business	Size	Natural logarithm of the enterprise's total assets at the end of the year.
	Profitability	ROA	Return on net assets = net profit/total assets.
	Debt capacity	LEV	Gearing ratio = total liabilities/total assets.
	Growth capacity	Growth	Operating income growth rate = increase in operating income for the year/operating income for the previous year.
	Percentage of fixed assets	Fixed	Percentage of fixed assets = fixed assets/total assets.
	Board size	Board	Total number of board members.
	Annual dummy variables	Year	
	Industry dummy variables	Ind	
	Regional dummy variables	Province	
Intermediate variables	Cohort effect empowerment	CE	Average value of digital transformation for companies in the same subsector.
	Technology absorption empowerment	TA	Number of technical staff as a percentage.
	Talent introduction empowerment	TI	Number of postgraduate and above employees/total number of employees.
	Innovation integration empowerment	PW	Patent knowledge width.

3.3. Sample Selection and Data Sources

The data for the list of enterprises that carried out industrial interconnection used in this paper were obtained from the Industrial Internet pilot demonstration projects released by the State Ministry of Industry and Information Technology in 2018–2020, with an initial sample of 258 projects. Nonmanufacturing enterprises, universities, institutions, unlisted enterprises, repeatedly selected enterprises were excluded, and the parent companies of selected enterprises were integrated, and a total of 85 A-share listed manufacturing enterprises that implemented industrial interconnection were finally screened as the treatment group sample for the study. The control group used in this paper for matching was derived from the balanced panel data of A-share listed companies in the manufacturing industry from the Cathay United database (CSMAR), spanning 2012–2020. To reduce the impact of outliers, samples with delisting, ST, and severely missing data during the period were excluded, and the continuous variables were tailed off.

4. Analysis of Empirical Results

4.1. Sample Profile and Descriptive Statistics

Tables 2 and 3 show the results of the main variables' descriptive statistics and correlation analysis Among them, the variable DT1, which characterizes the level of digital transformation of enterprises, has a mean value of 0.920, a standard deviation of 1.345, and a maximum value of 9.907, while the replacement variable DT2, which characterizes the digital transformation of enterprises, has a mean value of 1.078, a standard deviation of 1.242, and a maximum value of 4.875. It can be seen that there is a large variation in the level of digital transformation among the sample enterprises. The mean value of the variable treat was 0.013, and the listed manufacturing companies selected for the Industrial Internet pilot project accounted for 1.3% of the total sample manufacturing companies. The digitization data of the sample enterprises is summarized in Table 4. As can be seen from the table, the digital transformation level of manufacturing enterprises' DT1 mean value increased from 0.741 in 2012 to 0.898 in 2020, and DT2 mean value increased from 0.448 in 2012 to 1.619 in 2020, with the digital transformation level of manufacturing enterprises steadily increasing. It can be seen that the maximum level of digitization increased significantly in 2015, probably due to the positive impact of the Industrial Internet policy proposed in 2015, and the investment in digital transformation by manufacturing companies has increased significantly in the last three years since the Industrial Internet pilot was proposed in 2018.

Table 2. Descriptive statistics.

Variables	Observations	Average	Standard Deviation	Minimum Value	Median	Maximum Value
DT1	11,605	0.820	1.345	0.000	0.340	9.907
DT2	11,605	1.078	1.242	0.000	0.693	4.875
treat	11,605	0.013	0.112	0.000	0.000	1.000
list	11,605	0.047	0.211	0.000	0.000	1.000
Size	11,605	22.205	1.170	19.831	22.082	26.027
LEV	11,605	0.412	0.190	0.044	0.406	0.901
ROA	11,605	0.037	0.066	−0.424	0.037	0.221
Growth	11,605	0.146	0.272	−0.366	0.088	2.571
Board	11,605	8.471	1.627	0.000	9.000	18.000
Fixed	11,605	0.224	0.131	0.015	0.201	0.633

Table 3. Correlation analysis.

	DT	DT2	Treat	Size	LEV	ROA	Growth	Board	Fixed
DT1	1								
DT2	0.216 ***	1							
treat	0.0636 ***	0.102 ***							
size	−0.0637 ***	0.0860 ***	0.287 ***	1					
LEV	−0.0801 ***	−0.0112	0.120 ***	0.468 ***	1				
ROA	−0.0797 ***	0.0008	0.0302 ***	0.0298 ***	−0.363 ***	1			
Growth	0.0260 ***	0.0714 ***	−0.00204	0.0448 ***	0.00428	0.247 ***	1		
Board	−0.0579 ***	−0.0714 ***	0.0917 ***	0.280 ***	0.155 ***	0.0190 **	−0.0326 ***	1	
Fixed	−0.0559 ***	−0.272 ***	−0.0136	0.100 ***	0.145 ***	−0.109 ***	−0.170 ***	0.0955 ***	1

***, ** denote significant at the 1%, 5% levels, respectively.

4.2. Score Propensity Matching and Balance Tests

After calculating the propensity score using the logit regression method, the five nearest neighbors were matched with put-back. The kernel density curves of the experimental and control groups before and after matching are shown in Figure 1. It can be seen that the distribution of the left part of the kernel density curve before matching is looser, indicating that there are apparent differences between the experimental and control groups, and the distribution of the kernel density curve after matching tends to be the same, indicating that the systematic bias is overcome after matching and the common test trend hypothesis is satisfied. The balance test results before and after matching are shown in Table 5. It can be seen that only the variables fixed and growth satisfied the no-significant-difference test between the experimental and control groups before matching. After matching, the *p*-values of the variables were all greater than 0.1. The standard deviations were below 5%, indicating that the gap between the experimental and control groups had been eliminated mainly after the score propensity matching, satisfying the balance test hypothesis.

Table 4. Digitization profile of sample companies.

Year	Observations	DT1			DT2		
		Average	Min	Max	Average	Min	Max
2012	1027	0.741	0	9.195	0.448	0	3.638
2013	1120	0.752	0	8.209	0.549	0	3.738
2014	1105	0.670	0	6.059	0.760	0	3.871
2015	1159	0.836	0	9.907	1.088	0	4.143
2016	1254	0.847	0	8.637	1.159	0	4.466
2017	1336	0.812	0	7.948	1.305	0	4.718
2018	1550	0.873	0	8.907	0.909	0	4.745
2019	1551	0.874	0	7.912	1.482	0	4.875
2020	1503	0.898	0	8.426	1.619	0	4.875
Full sample	11,605	0.820	0	9.907	1.078	0	4.875

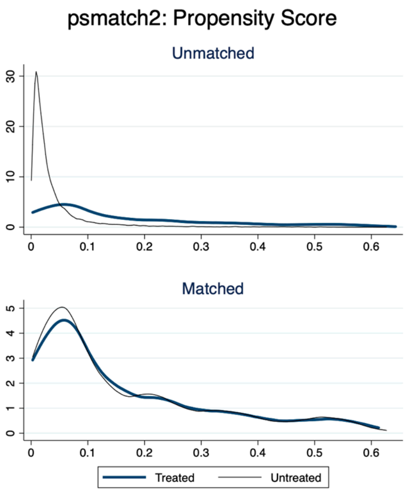

Figure 1. Kernel density curves before and after matching.

Table 5. Balance test.

Variables	Does It Match	Average Value		Standard Deviation/ %	Bias Reduction Rate/ %	*t*-Test	
		Processing Group	Control Group			t	$p > \|t\|$
Size	Not matched	23.726	22.131	130.6		32.26	0.000
	After matching	23.722	23.721	0.1	100.0	0.01	0.992
LEV	Not matched	0.51494	0.40663	61.1		13.04	0.000
	After matching	0.5155	0.52115	−3.2	94.8	−0.54	0.590
ROA	Not matched	0.04595	0.0368	16.3		3.16	0.002
	After matching	0.04562	0.04563	−0.0	100.0	−0.00	0.999
Growth	Not matched	0.14348	0.14638	−1.2		−0.24	0.809
	After matching	0.14344	0.14721	−1.5	−30.1	−0.27	0.786
Board	Not matched	9.1429	8.4384	38.4		9.86	0.000
	After matching	9.1468	9.1929	−2.5	93.5	−0.36	0.718
Fixed	Not matched	0.21625	0.2246	−6.0		−1.44	0.149
	After matching	0.21651	0.21884	−1.7	72.2	−0.26	0.792

4.3. Baseline Regression Analysis

Table 6 shows the results of the benchmark regression of the impact of industry connectivity on the digital transformation of manufacturing firms. The coefficient on the core explanatory variable treat is the net effect of industry interconnection on the digital transformation of manufacturing firms. Model (1) and model (2) are the results of the traditional double difference model estimation, and model (3)–model (8) is the result of the double difference model estimation after score propensity matching. Models (2), (4), (6), and (8) add control variables to models (1), (3), (5), and (7). The Hausman test results reject random effects, and therefore a fixed effects model was chosen for estimation, with models (1)–(4) controlling for individual firm and year fixed effects. It can be seen that the explanatory variable treat of the regression coefficient is positive at the 1% significance level. Models (5) and (6) control for industry and time fixed effects, and models (7) and (8) control for province, industry, and time fixed effects. The regression coefficient of the explanatory variable treat is positive at the 5% significance level, indicating that the implementation of the Industrial Internet demonstration pilot project since 2018 has had a positive impact on the level of digital transformation of manufacturing enterprises and that the pilot policy has prompted enterprises to engage in industrial interconnection. The Industrial Internet is an essential carrier for the manufacturing industry's digitization, networking, and intelligence. Manufacturing enterprises have increased the degree of investment in digital construction by joining application platforms and other carrier forms to achieve digital transformation, affirming the positive role of the Industrial Internet pilot.

Table 6. Baseline regression results.

Variables	**DID**				**PSM-DID**			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
treat	0.3837 ***	0.4181 ***	0.3889 ***	0.4188 ***	0.3811 **	0.3899 **	0.3872 **	0.3941 **
	(0.1044)	(0.1025)	(0.1051)	(0.1033)	(0.1841)	(0.1819)	(0.1747)	(0.1727)
Size		0.1344 ***		0.1421 ***		−0.0045		−0.0133
		(0.0359)		(0.0347)		(0.0116)		(0.0126)
LEV		−0.4393 ***		−0.4767 ***		−0.8004 ***		−0.7802 ***
		(0.1279)		(0.1307)		(0.0882)		(0.0909)
ROA		−2.4253 ***		−2.4344 ***		−2.4978 ***		−2.2354 ***
		(0.2419)		(0.2492)		(0.2598)		(0.2668)
Growth		0.1316 ***		0.1281 ***		0.2455 ***		0.2647 ***
		(0.0496)		(0.0497)		(0.0571)		(0.0612)
Board		−0.0142		−0.0097		−0.0031		−0.0010
		(0.0109)		(0.0107)		(0.0073)		(0.0075)
Fixed		1.1265 ***		1.0574 ***		0.2017 *		0.2962 ***
		(0.1663)		(0.1674)		(0.1090)		(0.1107)
Year	YES	YES	YES	YES	YES	YES	YES	YES
Industry	NO	NO	NO	NO	YES	YES	YES	YES
Province	NO	NO	NO	NO	NO	NO	YES	YES
Firm	YES	YES	YES	YES	NO	NO	NO	NO
_cons	0.8154 ***	−2.0503 ***	0.8091 ***	−2.2329 ***	0.8256 ***	1.2917 ***	0.8236 ***	1.4255 ***
	(0.0077)	(0.7931)	(0.0077)	(0.7550)	(0.0121)	(0.2414)	(0.0121)	(0.2645)
N	11,605	11,605	11,440	11,440	11,441	11,441	10,939	10,939
adj.	0.6312	0.6419	0.6324	0.6422	0.1239	0.1391	0.1505	0.1644

Note: Heteroskedasticity robust standard errors in brackets; ***, **, and * denote significant at the 1%, 5%, and 10% levels, respectively; R2_a is adjusted R^2; all treated the same below.

4.4. Robustness Tests

4.4.1. Parallel Trend Test

Applying traditional double differences requires the treatment and control groups to have a parallel trend before the event. The results of the parallel trend test are shown in Figure 2. It can be seen that the coefficient of the effect of digital transformation before the implementation of the Industrial Internet pilot fluctuates around 0, indicating that there is no significant difference between the treatment and control groups before the pilot of the Industrial Internet project, satisfying the parallel trend assumption. The coefficient was significantly positive and rose significantly after the implementation of the Industrial Internet pilot, with a confidence interval excluding 0, indicating that the implementation of the Industrial Internet project began to show its effect on promoting digital transformation in manufacturing enterprises.

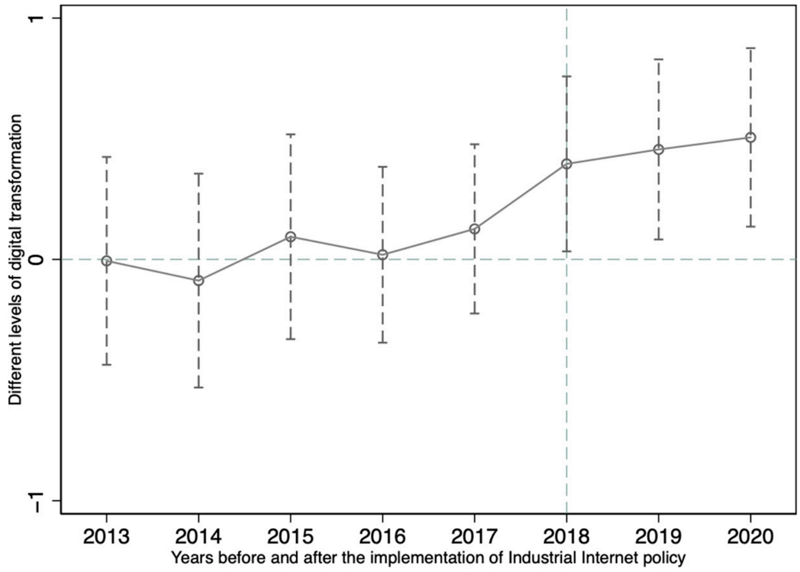

Figure 2. Parallel convergence test diagram.

4.4.2. Placebo Test

In order to control for random shocks to control group firms from the Industrial Internet project, this paper obtained the estimated coefficients of the 1000 Industrial Internet explanatory variables by randomly generating an experimental group and conducting a placebo test with 1000 random repeated samples according to the benchmark regression model. The specific results of the placebo test are shown in Figure 3. According to the kernel density distribution, it can be seen that the estimated coefficients of the placebo test obey a normal distribution with a mean close to 0 and are significantly different from the true regression value compared to the true coefficient of the benchmark regression of 0.417. In addition, below the 1% significance level, it indicates that the expected results of the placebo test were met. Thus, the placebo test results under random sampling suggest that the contribution of the Industrial Internet to the digital transformation of manufacturing firms is not generated for other unobservable omitted variables, indicating the robustness of the results.

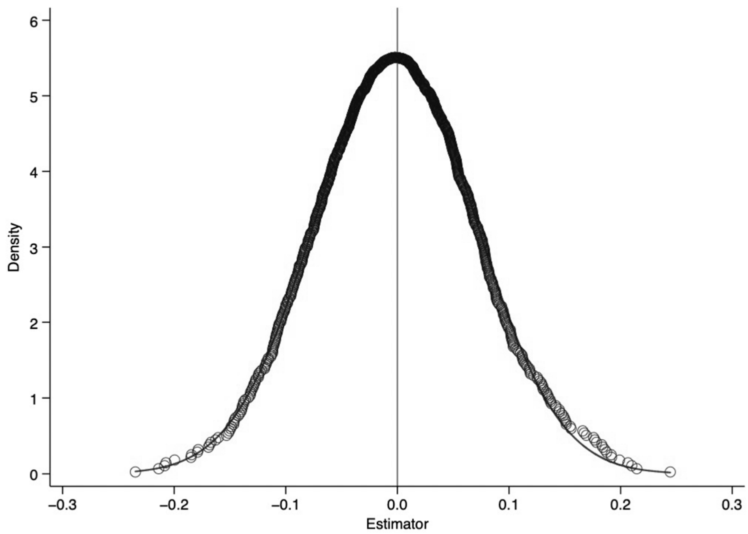

Figure 3. Placebo test results.

4.4.3. Replacement of Explanatory Variables

In order to ensure the robustness of the conclusion, the robustness test replaces the relevant measures of the degree of digital transformation of the explanatory variables. Some scholars use the number of digital-transformation-related word frequencies to measure digital transformation. Considering the accessibility and realism of the data, we draw on Wu Fei [54] to construct a characteristic word map of digital transformation and inscribe the intensity of the digital transformation of enterprises with the help of crawler technology to attribute the word frequency share of digital transformation keywords in their annual reports. Specific digital transformation keywords include artificial intelligence technology, big data technology, cloud computing technology, blockchain technology, digital technology application, and its subdivisions. The frequency of digital keywords in annual reports reflects the degree of enterprises' investment and attention to this aspect, so this paper sums up their word frequencies. It uses them as a replacement indicator to measure enterprises' digital transformation degree. Table 7 shows the results of the robustness test of the Industrial Internet on the degree of digital transformation of manufacturing enterprises. It can be seen that both the double difference model and the double difference model with propensity matching of scores show that the regression coefficient of manufacturing enterprises' participation in the Industrial Internet is significantly positive at the 5% statistical level, which indicates that the participation of manufacturing enterprises in the Industrial Internet project significantly contributes to the robustness of the results of digital transformation of enterprises.

Table 7. Robustness tests for replacement of explanatory variables.

Variables	(1)	(2)	(3)	(4)
	DID	DID	PSM-DID	PSM-DID
treat	0.2046 ** (0.0931)	0.2137 ** (0.0930)	0.2104 ** (0.0935)	0.2195 ** (0.0933)
Size		0.2407 *** (0.0243)		0.2541 *** (0.0250)
Lev		0.0908 (0.0871)		0.1434 (0.0891)
Roa		−0.2133 (0.1600)		−0.1379 (0.1709)
Growth		−0.0696 ** (0.0315)		−0.0772 ** (0.0313)
Board		0.0211 ** (0.0089)		0.0198 ** (0.0091)
Fixed		−0.5479 *** (0.1225)		−0.6521 *** (0.1259)
_cons	1.0756 *** (0.0066)	−4.3436 *** (0.5298)	1.0778 *** (0.0066)	−4.6371 *** (0.5452)
Firm	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
N	11,606	11,606	11,442	11,442
R2_a	0.6826	0.6887	0.6847	0.6912

***, ** denote significant at the 1%, 5% levels, respectively.

5. Further Analysis

5.1. Impact Mechanism Test

Industrial Internet empowers digital transformation of manufacturing industry. Further, we validate the transmission mechanism of Industrial Internet on accelerating enterprise digitalization, and analyze the impact and digital empowerment mechanism of Industrial Internet on four latitudes of digitalization, technology absorption, talent introduction, and innovation integration of industry cohort enterprises. Referring to the research ideas of Jiang [55] and Wen [56], the mediating effect regression model is constructed as follows:

$$DT_{i,t} = \alpha_1 + \beta_1 treat_{i,t} + \gamma \sum controls_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

$$\mathrm{M_{i,t}} = \alpha_1 + \beta_1 treat_{i,t} + \gamma \sum controls_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

$$DT_{i,t} = \alpha_1 + \beta_1 treat_{i,t} + \beta_2 \mathrm{M_{i,t}} + \gamma \sum controls_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

where i denotes individual firm, t denotes year, M denotes the mediating variables, the coefficient in model (1) β_1 is the total effect of the Industrial Internet on the level of digital transformation, the coefficient in model (2) β_1 is the effect of the Industrial Internet on the mediating variables, the coefficient in model (3) β_1 is the direct effect of the Industrial Internet on the level of digital transformation after controlling for the effects of the innovation mediating variables, and the coefficient β_2 is the effect of the mediating variable on the level of digital transformation after controlling for the effect of the independent variable. The coefficient of model (2) β_1 and the coefficient of model (3) β_2 are tested in turn; if both are significant, then the mediating effect is valid, if at least one is insignificant, then a bootstrap method test is required. The test for mediating effects is shown in Table 8, where each mediating variable is measured as follows:

(1) Latitude of cohort effect

Referring to the study of Chunhui Huo [57], the digital transformation of enterprises in the same subsector was selected to take the mean value for measurement.

(2) Talent introduction latitude

Referring to the study of Yang Wei [58], the number of employees with a master's degree or above was selected for measurement, and the level of high-level manpower structure can reflect the degree of attention and introduction of talents in enterprises.

(3) Technology absorption latitude

Referring to the study of Huang [59], the ratio of the number of technicians to the total number of employees in the enterprise was selected for measurement.

(4) Innovation integration latitude

The patent quality of the knowledge width measure was selected for measurement. The patent is an essential carrier of innovation, and patent knowledge width describes the technical scope covered by a patent, which can reflect the integration of enterprise heterogeneous knowledge more comprehensively [60]. Referring to the study of J. Zhang [61] using the Herfindahl–Hirschman index method measure, the formula is PW = 1 − Σb2, where b is the proportion of the large group classification of each patent's IPC classification number.

In the analysis of the model results mediated by the cohort effect in Table 5, column (1) is consistent with the aforementioned benchmark model, and the coefficient of column (2), 0.0619, is significantly positive at 5%, indicating that the coefficient of the Industrial Internet effect on the cohort effect is significantly positive. Based on the hypothesis analysis, the digital cohort effect on promoting the digitalization of enterprises, while the coefficients of treat and CE on DT are 0.4134 at 1% significant and 0.0924 at 10% significant, respectively, indicating the mediating role of the digital cohort effect, which verifies hypothesis H2, that the Industrial Internet can enhance the digital transformation of enterprises by promoting the digital cohort effect of the same industry, and as the Industrial Internet develops deeply, the digital cohort effect plays an empowering effect of promoting the digital transformation of enterprises through the digital synergy and influence within the industry.

Table 8. Mechanism test results.

Variables	Cohort Effect Empowerment			Technology Absorption Empowerment			Talent Introduction Empowerment			Innovation Integration Empowerment		
	DT	CE	DT	DT	TI	DT	DT	TA	DT	DT	PW	DT
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Treat	0.4192 ***	0.0619 **	0.4134 ***	0.4496 ***	0.7659 *	0.4300 **	0.4338 ***	0.5276 ***	0.6080 **	0.5592 **	0.1212 ***	0.5449 **
	(0.1575)	(0.0293)	(0.1587)	(0.1679)	(0.4021)	(0.1682)	(0.1616)	(0.1286)	(0.3087)	(0.2199)	(0.0235)	(0.2201)
CE			0.0924 *									
			(0.0482)									
TI						0.0256 *						
						(0.0135)						
TA									0.0278 ***			
									(0.0029)			
PW												0.1176 ***
												(0.0416)
Size	0.1345 **	0.0017	0.1344 **	0.1336 **	0.7259 ***	0.1150 *	0.1431 ***	0.7849 ***	−0.0288	0.1020 **	0.0523 ***	0.0958 *
	(0.0538)	(0.0181)	(0.0537)	(0.0651)	(0.2262)	(0.0655)	(0.0545)	(0.0231)	(0.0243)	(0.0518)	(0.0094)	(0.0517)
LEV	−0.4366 **	0.1199 **	−0.4477 **	−0.5133 **	−1.6079 **	−0.4722 **	−0.4195 **	−0.1098	−0.6224 ***	−0.2436	−0.0832 **	−0.2338
	(0.1903)	(0.0575)	(0.1903)	(0.2122)	(0.6798)	(0.2078)	(0.1880)	(0.1244)	(0.1649)	(0.1841)	(0.0334)	(0.1841)
ROA	−2.4325 ***	−0.1689 **	−2.4169 ***	−2.6549 ***	−0.7772	−2.6350 ***	−2.3706 ***	1.1383 ***	−2.6349 ***	−2.1160 ***	−0.0644	−2.1084 ***
	(0.2783)	(0.0699)	(0.2768)	(0.3392)	(0.5676)	(0.3362)	(0.2791)	(0.2407)	(0.3831)	(0.2944)	(0.0562)	(0.2939)
Growth	0.1365 ***	−0.0094	0.1374 ***	0.1396 **	−0.1544	0.1435 **	0.1406 ***	−0.0011	0.2616 ***	0.1242 **	0.0228 *	0.1216 **
	(0.0502)	(0.0155)	(0.0503)	(0.0650)	(0.1078)	(0.0650)	(0.0510)	(0.0419)	(0.0614)	(0.0592)	(0.0121)	(0.0589)
Board	−0.0140	0.0073	−0.0147	0.0007	0.0761	−0.0012	−0.0116	0.0148	−0.0111	−0.0275*	0.0029	−0.0278 *
	(0.0179)	(0.0056)	(0.0180)	(0.0230)	(0.0477)	(0.0226)	(0.0179)	(0.0118)	(0.0148)	(0.0159)	(0.0034)	(0.0159)
Fixed	1.1416 ***	−0.2145 **	1.1614 ***	1.0983 ***	−0.8249	1.1194 ***	1.2089 ***	−0.0741	0.2960	0.9358 ***	−0.0419	0.9407 ***
	(0.2279)	(0.0905)	(0.2266)	(0.2939)	(0.6342)	(0.2915)	(0.2326)	(0.1632)	(0.1996)	(0.2399)	(0.0475)	(0.2399)
_cons	−2.0604 *	1.8025 ***	−2.2269 *	−2.0451	−11.9929**	−1.7385	−2.2944 *	−11.5574 ***	1.2822 **	−1.3676	−0.8180 ***	−1.2714
	(1.1923)	(0.3894)	(1.1887)	(1.4623)	(4.9223)	(1.4700)	(1.2104)	(0.4717)	(0.5005)	(1.1489)	(0.2068)	(1.1494)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	11,531	11,531	11,531	8224	8224	8224	11,318	11,318	11,318	8060	8060	8060
R2_a	0.6390	0.9236	0.6393	0.6675	0.8966	0.6684	0.6391	0.5550	0.1033	0.6632	0.3957	0.6636

***, **, * denote significant at the 1%, 5%, 10% levels, respectively.

For the model results in the analysis of talent introduction intermediary in Table 5, column (1) is consistent with the aforementioned benchmark model, and the coefficient of column (2) 0.7659 is significantly positive at 10%, indicating that the coefficient of the impact of Industrial Internet on cohort effect is significantly positive. Based on the hypothesis analysis, the Industrial Internet significantly promotes the introduction of talent in enterprises, while the coefficients of treat and TI on DT are 0.4300 at 5% significant and 0.0256 at 10% significant, respectively, indicating the mediating role of the talent introduction effect, which validates test H5, that the Industrial Internet can promote the talent introduction mechanism of enterprises to empower their digital transformation. The Industrial Internet motivates companies to bring in high-level talent, enhance organizational digital literacy through talent inflow, and promote digital transformation of companies.

For the analysis of the model results for the mediation of technology absorption in Table 5, column (1) is consistent with the aforementioned benchmark model, and the coefficient of column (2) 0.5276 is significantly positive at 1%, indicating that the coefficient of the effect of Industrial Internet on technology absorption is significantly positive. Based on the hypothesis analysis, the Industrial Internet significantly promotes the technology absorption of enterprises, while the coefficients of treat and TA on DT are 0.6080 at 5% significant and 0.0278 at 1% significant, respectively, indicating the mediating role of the technology absorption effect, which validates test H3, that the Industrial Internet can empower the digital transformation of enterprises by promoting their technology absorption. The Industrial Internet motivates enterprises to pay attention to technology and R&D, adjust their resource allocation, and achieve technology transformation by increasing technology absorption to facilitate their digital transformation.

For the model results analysis of the intermediary of enterprise innovation integration in Table 5, column (1) is consistent with the aforementioned benchmark model, and the coefficient of column (2), 0.1212, is significantly positive at 1%, indicating that the coefficient of the impact of the Industrial Internet on enterprise innovation integration is significantly positive. Based on the hypothesis analysis, the Industrial Internet significantly promotes enterprise innovation integration, while the coefficients of treat and PW on DT are 0.5449 at 5% significant and 0.1176 at 1% significant, respectively, indicating the mediating effect of enterprise innovation integration effect, which validates test H5, that the Industrial Internet can promote enterprise innovation integration to empower digital transformation. The Industrial Internet prompts enterprises to use more cross-domain knowledge in the R&D innovation process, which enhances the richness and complexity of technological innovation, promotes enterprises to improve the quality of innovation integration, and facilitates the landing of diversified technologies to accelerate enterprise digitalization.

5.2. Heterogeneity Analysis

Group-based regression is used for heterogeneity analysis to test whether the Industrial Internet has differential impacts on enterprises of different types, different degrees of diversification, different technology intensities, and different regions. The results of the heterogeneity analysis are shown in Table 9.

Table 9. Heterogeneity analysis results.

Variables	Nature of Property Rights		Diversification of Operations		Intensity of Elements		Geographical Location	
	State-Owned Enterprises	Non-State-Owned Enterprises	Diversified Enterprises	Nondiversified Enterprises	Technology-Intensive Enterprises	Non-Technology-Intensive Enterprises	Eastern Region	Noneastern Region
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treat	0.4393 *	0.3717 **	0.4977 *	0.3781	0.5070 ***	0.2575	0.6237 **	0.2048
	(0.2308)	(0.1884)	(0.2583)	(0.2339)	(0.1846)	(0.2846)	(0.2742)	(0.1346)
Size	0.1287	0.1567 ***	0.1861 ***	0.1116	0.1243	0.1937 ***	0.1676 **	0.1304 **
	(0.1311)	(0.0562)	(0.0718)	(0.0982)	(0.0841)	(0.0581)	(0.0814)	(0.0613)
LEV	−0.5674	−0.4250 **	−0.2299	−0.7720 ***	−0.7720 **	−0.0753	−0.6272 **	−0.2733
	(0.4598)	(0.2108)	(0.2624)	(0.2905)	(0.3285)	(0.1816)	(0.3145)	(0.2284)
ROA	−2.1901 ***	−2.5532 ***	−1.7627 ***	−3.1039 ***	−2.6823 ***	−1.9724 ***	−2.5674 ***	−2.2704 ***
	(0.6695)	(0.3144)	(0.3548)	(0.4838)	(0.3896)	(0.3262)	(0.4272)	(0.3518)
Growth	−0.0668	0.1635 ***	0.1844 ***	0.0935	0.1043	0.1795 **	0.1873**	0.0762
	(0.0825)	(0.0566)	(0.0658)	(0.0969)	(0.0679)	(0.0808)	(0.0810)	(0.0575)
Board	−0.0463	0.0053	−0.0168	−0.0084	−0.0263	−0.0063	−0.0108	−0.0078
	(0.0323)	(0.0233)	(0.0229)	(0.0221)	(0.0302)	(0.0178)	(0.0289)	(0.0196)
Fixed	1.3501 **	1.1652 ***	1.2328 ***	1.6168 ***	2.0179 ***	0.7339 ***	1.5967 ***	0.7510 ***
	(0.5410)	(0.2500)	(0.3064)	(0.3960)	(0.3977)	(0.2501)	(0.3643)	(0.2712)
_cons	−1.7694	−2.6553 **	−3.3845 **	−1.4612	−1.5074	−3.7809 ***	−2.7278	−2.1170
	(3.0360)	(1.2101)	(1.5515)	(2.1682)	(1.8604)	(1.2774)	(1.7676)	(1.3390)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	3038	8520	6118	4827	6192	5396	5889	5710
R2_a	0.6994	0.6218	0.6704	0.6799	0.6487	0.6134	0.6337	0.6505

***, **, * denote significant at the 1%, 5%, 10% levels, respectively.

(1) Heterogeneity analysis of enterprise ownership nature. According to the different ownership nature of enterprises, the sample enterprises are divided into SOEs and sub-SOEs. The treat coefficient of Industrial Internet pilot of state-owned enterprises and non-state-owned enterprises is significantly positive, and there are differences in the coefficient and significance level. It shows that regardless of whether they are state-owned enterprises or non-state-owned enterprises, Industrial Internet pilot can promote the digital transformation of enterprises. Enterprises with different property rights are different in terms of operation mechanism and business model. State-owned enterprises usually focus more on grasping the overall development of the industry, while non-state-owned

enterprises pay more attention to their own resource conditions and advantages to enter the market. Under the influence of Industrial Internet, digital enabling effects are different.

(2) Analysis of heterogeneity of enterprise diversified operation. According to the differences in enterprises' cross-industry business strategies, there are qualitative differences in the degree of diversification and specialization. In diversified enterprises, the effect coefficient of Industrial Internet in promoting digital transformation is significantly positive. The Industrial Internet treat coefficient of enterprises with a single operation is not significant, indicating that whether enterprises carry out diversified operation across industries has obvious differences in promoting digital transformation of Industrial Internet. In the face of industrial interconnection, digital operation is the inevitable trend of diversified operation. Enterprises realize digital transformation by integrating resources, developing new business areas, and broadening marketing channels through cross-industry business strategies, so as to bring more economic benefits and social values.

(3) Analysis of heterogeneity of industrial factor intensity. According to the different degrees of industry factor intensity, enterprises are divided into two types: technology-intensive and non-technology-intensive. The grouping regression results are shown in columns (5) and (6) of Table 9. The digital empowerment effect of enterprises of Industrial Internet exists in technology-intensive industries and is not significant for non-technology-intensive industries. The treat coefficient is higher for technology-intensive industries than for non-technology-intensive industries. This may be due to the fact that technology-intensive enterprises have advanced production processes and equipment, and with the help of the Industrial Internet platform, they can more quickly adapt to the industrial interconnection model, achieve total factor linkage, and promote digital transformation.

(4) Analysis of geographical location heterogeneity. According to different geographical locations of enterprises, it is divided into two subsamples: eastern and noneastern. The grouped regression results are shown in columns (7) and (8) of Table 9. The treat coefficient in the eastern region is 0.6237 and is significantly positive at the 5% level, while the coefficient in the noneastern region is insignificant. Due to the superior geographical location of the eastern region, it is easier to obtain digital technology support, and the information industry foundation is relatively solid, which can provide a good development environment for talents. The resource endowment, including capital, talent, and technology, is relatively rich in the central and western regions, providing a good environmental space for the Industrial Internet effect to play. There is a certain imbalance in the impact of regional factor development gap on digital transformation.

6. Conclusions and Discussion

6.1. Conclusions

The development of China's industrial interconnection innovation has entered a critical period, and the emerging technologies represented by the Industrial Internet are gradually becoming a new engine to help promote industrial digitization and drive digital industrialization. This paper conducted a quasi-natural experiment around the "Industrial Internet Pilot Demonstration Project" selected by the Ministry of Industry and Information Technology of the People's Republic of China. Based on the data of manufacturing A-share listed companies from 2012 to 2020, this study empirically examined the impact and mechanism of Industrial Internet pilots' effect on manufacturing enterprises' digital transformation. The results of the study indicate that the development of Industrial Internet projects significantly promotes manufacturing enterprises to increase digital investment, i.e., industrial interconnection empowers digital transformation of enterprises. Robustness tests proved the reliability of the findings. The results of the impact mechanism test show that the Industrial Internet empowers the digital transformation of enterprises through the digital cohort effect, technology absorption, talent introduction, and innovation integration. The heterogeneity test results show that there is significant heterogeneity in the impact of the Industrial Internet on the digital transformation of enterprises at the enterprise, industry, and regional levels, with more substantial digital effects of the Industrial Internet empowerment for technology-intensive enterprises, diversified business enterprises, and enterprises in the eastern region, and no significant impact of the Industrial Internet on the digitalization of non-technology-intensive enterprises, nondiversified business enterprises, and enterprises in the western region.

6.2. Discussion

Based on the above findings, the following recommendations are made:

First, it is important to adhere to industrial policies to promote the construction of Industrial Internet platforms and the formation of a complete Industrial Internet ecology. We should further increase the publicity of industrial interconnection demonstration and the application promotion of vertical subdivision industries, give full play to the function of policy guidance, and continuously promote the Industrial Internet project to land.

Second, we should accelerate the gathering of industry technology, talent, and innovation elements, and strengthen the construction of comprehensive digital capabilities. The government should establish an effective mechanism to motivate technical talents to continuously carry out digital innovation, explore new transformation methods, and carry out further cross-border cooperation with the help of the Industrial Internet platform. Through technological innovation, structural adjustment, and change and upgrading of traditional manufacturing industries, new growth will be fostered, promoting the optimization and adjustment of industrial structure to drive rapid economic development.

Third, we should strengthen multibody integration and cooperation to promote the balanced development of digitalization. We should adhere to the situation, give targeted support to enterprises in different industries and at different scales, and accelerate the introduction of comprehensive policies for various enterprises with special planning packages. We should improve the policy body synergy mechanism, strengthen regional linkage and enterprise cooperation in the east and west, cross the digital divide between regions, industries, and enterprises, and fully release the positive effect of the Industrial Internet to empower the digitalization of manufacturing.

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References

1. Cao, Z.Y. Research on new manufacturing model to promote high-quality development of China's industry in the context of digital economy. *Theor. Discuss.* **2018**, 99–104. [CrossRef]
2. Zhou, J. Intelligent manufacturing—The main direction of "Made in China 2025". *China Mech. Eng.* **2015**, *26*, 2273–2284.
3. Dixit, A.; Jakhar, S.K.; Kumar, P. Does lean and sustainable manufacturing lead to Industry 4.0 adoption: The mediating role of ambidextrous innovation capabilities. *Technol. Forecast. Soc. Chang.* **2022**, *175*, 1–9. [CrossRef]
4. Huang, J.F. Understanding and planning contemporary technological and industrial change with smart and connected thinking. *Econ. Manag. Stud.* **2017**, *38*, 80–89.
5. Tan, X.J.; He, J.J.; He, S.X. Industrial interconnection towards cloud-based supply chain information collaboration. *Comput. Syst. Appl.* **2020**, *29*, 6.
6. Zhao, J.; Qi, X.R.; Wu, J.F.; Wu, C. Theory, analysis, evaluation and implementation platform of future industrial Internet loosely coupled structures. *Comput. Integr. Manuf. Syst.* **2021**, *27*, 1249–1255.
7. Tan, X.J.; He, J.J.; Wang, W.Q. Research on collaborative scheduling of industrial interconnection based on Q-Learning algorithm. *Ind. Eng. Manag.* **2021**, *170*, 1–10.

8. He, J.J.; Wu, X.M.; Li, J.X.; He, S.X. Multi-energy conversion based on game theory in the industrial interconnection. *PLoS ONE* **2021**, *16*, e0245622. [CrossRef]
9. Zuo, W.M.; Qiu, X.X. Industrial Internet industry cluster ecosystem construction—A qualitative study based on text mining. *Sci. Technol. Prog. Countermeas.* **2022**, *39*, 83–93.
10. Wang, L.Y.; Li, S.N.; Wang, J.D. Quantitative evaluation of China's industrial Internet industrial policy—Based on PMC index model. *Ind. Technol. Econ.* **2022**, *41*, 151–160.
11. Feng, L.Q.; He, B.X.; Sun, H.Q. The effect of industrial internet support policies on the R&D investment of enterprises. *J. Jishou Univ. Soc. Sci. Ed.* **2023**, *44*, 78–88.
12. Shang, H.T.; Song, A.L. Does industrial Internet industrial policy promote digital transformation of enterprises. *Scientol. Res.* **2023**, 1–26. [CrossRef]
13. Du, Y.; Cao, L.; Tan, C. How can platformization help manufacturing enterprises cross the digital divide of transformation and upgrading?—Based on exploratory case study of zongshen group. *Manag. World* **2022**, *38*, 117–139.
14. Lu, F.C.; Chen, H. Industrial Internet, firm growth and value creation. *Econ. Manag.* **2023**, *45*, 5–24.
15. Guo, R.B.; Zhao, J. A threshold effect test on the impact of industrial Internet development on China's manufacturing upgrading. *Stat. Decis. Mak.* **2022**, *38*, 135–138.
16. Xu, X.C.; Zhang, M.H. Research on the measurement of the size of China's digital economy—Based on the perspective of international comparison. *China Ind. Econ.* **2020**, 23–41.
17. Zhao, T.; Zhang, Z.; Liang, S.K. Digital economy, entrepreneurial activity and highquality development—Empirical evidence from Chinese cities. *Manag. World* **2020**, *36*, 65–76.
18. Xia, X.; Chen, Z.; Zhang, H.L.; Zhao, M.J. High-quality development of agriculture: Digital empowerment and realization path. *China Rural Econ.* **2019**, 2–15.
19. Li, C.F.; Li, D.D.; Zhou, C. The mechanism of the role of digital economy in driving the transformation and upgrading of manufacturing industry—An analysis based on the perspective of industrial chain. *Bus. Res.* **2020**, 73–82.
20. Zhuang, C.Y.; Chen, G.H.; Liang, J.; Hou, J.; Cai, B.Q. Internet capabilities, dual strategy flexibility and knowledge creation performance. *Scientol. Res.* **2020**, *38*, 1837–1846+1910.
21. Chi, M.M.; Wang, J.J.; Wang, W.J. Research on the influence mechanism of corporate innovation performance in the context of digital transformation—A mixed method based on NCA and SEM. *Scientol. Res.* **2022**, *40*, 319–331.
22. He, F.; Liu, H.X. Assessment of the performance-enhancing effect of digital change in real enterprises from the perspective of digital economy. *Reform* **2019**, 137–148.
23. Qi, I.D.; Xiao, X. Enterprise management changes in the digital economy era. *Manag. World* **2020**, *36*, 135–152+250.
24. Chen, J.; Huang, S.; Liu, Y.H. From empowerment to enablement—Enterprise operation management in digital environment. *Manag. World* **2020**, *36*, 117–128+222.
25. Gregory Vial. Understanding digital transformation: A review and a research agenda. *J. Strateg. Inf. Syst.* **2019**, *28*, 118–144. [CrossRef]
26. Jong Hyuk Park. Advances in Future Internet and the Industrial Internet of Things. *Symmetry* **2019**, *11*, 244. [CrossRef]
27. Ma, N.F.; Yao, X.F.; Wang, K.S. Status and prospects of research on smart manufacturing for future Internet. *China Sci. Technol. Sci.* **2022**, *52*, 55–75.
28. Silva, I.; Viegas, C. An Effective Extension of Anti-Collision Protoco for RFID in the Industrial Internet of Things (IIoT). *Sensors* **2018**, *18*, 4426.
29. Beneath the iceberg: The second in a series of studies on China's industrial Internet 2019. In *Ariadne Consulting Series Research Report (No. 12, 2019)*; Shanghai IResearch Market Consulting Co., Ltd.: Shanghai, China, 2019; pp. 222–281.
30. Lv, M.Y.; Cheng, Q.Y. The impact of industrial Internet platform development on the transformation and upgrading of manufacturing industry: Effect and mechanism. *Humanit. Mag.* **2022**, *318*, 63–74.
31. Shi, Z.M.; Du, L. An empirical study on the impact of industrial Internet platform on industrial convergence. *Sci. Technol. Prog. Policy* **2020**, *39*, 59–68.
32. Zhao, Y.; Lai, W.Y. Analysis of factors influencing China's industrial Internet implementation capability based on TOE theory. *Manag. Mod.* **2021**, *41*, 25–28.
33. Dou, D.P.; Kuang, Z.J. Servitization of manufacturing and global value chain location enhancement—An analysis based on manufacturing firms. *Int. Bus. Res.* **2022**, *13*, 46–58.
34. Wang, Y.R.; Duan, Y.T.; Zhuo, S.F. Impact of Industrial Internet on Digital Innovation of Enterprises—Double Difference Validation Based on Propensity Score Matching. Science and Technology Progress and Countermeasures 1–10. Available online: http://kns.cnki.net/kcms/detail/42.1224.G3.20210624.1134.006.html (accessed on 2 March 2022).
35. Zhao, H.X.; Wang, M.J.; Wang, G.T. The Impact of Ecological Embedding of Industrial Internet Platforms on the Performance of Participating Firms' Exploratory Innovation [J/OL]. Science and Technology Progress and Countermeasures 1–10. Available online: http://kns.cnki.net/kcms/detail/42.1224.G3.20220413.1545.009.html (accessed on 13 May 2022).
36. Hess, T.; Matt, C.; Benlian, A.; Wiesboeck, F. Options for formulating a digital transformation strategy. *Mis Quart. Exec.* **2016**, *15*, 123–139.
37. Majchrzak, A.; Markus, M.L.; Wareham, J. designing for digital transformation: Lessons for information systems research from the study of ICT and societal challenges. *Mis Quart.* **2016**, *40*, 267–277. [CrossRef]

38. Lv, W.; Chen, J.; Liu, J. Smart manufacturing model and enterprise platform construction of industrial internet–a case study based on Haier Group. *China Soft Sci.* **2019**, 1–13.
39. Cai, C.W.; Qi, Y.D. Research on the empowerment path of industrial Internet for China's manufacturing industry. *Contemp. Econ. Manag.* **2021**, *43*, 40–48.
40. Tang, G.F.; Li, D. Research on reconstructing the service-oriented value creation system of manufacturing industry in the context of industrial internet. *Econ. Vert.* **2020**, 61–68.
41. Wu, J.; Chen, T.; Gong, Y.W.; Yang, Y.X. Theoretical framework and research outlook on digital transformation of enterprises. *J. Manag.* **2021**, *18*, 1871–1880.
42. Qiu, Y.; Guo, Z.M. A study on the mechanism and policy of digital economy to promote the value chain climbing of SMEs in China. *Int. Trade* **2019**, 12–20+66.
43. Wang, C.; Song, L.; Li, S.K. Industrial Internet platform: Development trends and challenges. *China Eng. Sci.* **2018**, *20*, 15–19. [CrossRef]
44. Wang, F.T.; Hao, X.L.; Yuan, Y. Digital business ecosystem characteristics: A comparison of data control and data coordination models. *South. Econ.* **2022**, *41*, 1–17.
45. Chen, Q.J.; Wang, Y.M.; Wan, M.F. Research on peer effect and influencing factors of enterprise digital transformation. *J. Manag.* **2021**, *18*, 653–663.
46. Li, Y.H.; Lan, Q.F.; Wu, W.F. Research on the supply chain diffusion mechanism of digital transformation of customer companies. *China Ind. Econ.* **2022**, *417*, 146–165.
47. He, S.L.; Li, J.; Zhou, Y.; Zhang, X. Current situation of industrial Internet platform application and development countermeasures. *Sci. Technol. Manag. Res.* **2021**, *41*, 132–137.
48. Sun, X.; Wu, Z.G. Research on the evolution of digital employment, development bottlenecks and strategies to promote digital employment. *Ind. Econ. Rev.* **2021**, *43*, 119–128.
49. Sun, X.B.; Su, J.H.; Qian, Y.; Zhang, D. Current status and future prospects of data empowerment research. *Res. Dev. Manag.* **2020**, *32*, 155–166.
50. Zheng, Y.H.; Sun, Y.M.; Yin, J.F. Industrial Internet Platform Data Empowerment, Absorptive Capacity and Digital Transformation of Manufacturing Enterprises. Science and Technology Progress and Countermeasures:1–12. Available online: http://kns.cnki.net/kcms/detail/42.1224.G3.20220714.1750.006.html (accessed on 6 April 2023).
51. Sun, X.B.; Zhang, M.C.; Wang, Y.X. A case study on the mechanism of industrial internet platform empowerment for data-based business ecosystem construction. *Manag. Rev.* **2022**, *34*, 322–337.
52. Huawei Technologies, IDC. Digital Platform White Paper—Digital Platforms Break through Enterprise Digital Transformation. 19 March 2019. Available online: https://e.huawei.com/cn/material/enterprise/ee02c2a1ab2a4e949fd78c9d470288fc (accessed on 21 October 2020).
53. Wang, T.N.; Wang, Y. Information technology investment, CEO overconfidence and firm performance. *Manag. Rev.* **2017**, *29*, 70–81.
54. Wu, F.; Hu, H.Z.; Lin, H.Y.; Ren, X.Y. Corporate digital transformation and capital market performance—Empirical evidence from stock liquidity. *Manag. World* **2021**, *37*, 130–144.
55. Jiang, T. Mediating and moderating effects in empirical studies of causal inference. *China Ind. Econ.* **2022**, *410*, 100–120.
56. Wen, Z.L.; Ye, B.J. Mediation effect analysis: Methodology and model development. *Adv. Psychol. Sci.* **2014**, *22*, 731–745. [CrossRef]
57. Huo, C.H.; Lv, M.X.; Xu, X.N. The "cohort effect" of digital transformation and high-quality development of enterprises: Empirical evidence based on listed manufacturing companies. *Sci. Technol. Prog. Countermeas.* **2023**, *40*, 77–87.
58. Yang, W.; Kong, D. Min. Intra-firm pay gap and human capital restructuring. *Financ. Res.* **2019**, 150–168.
59. Huang, K.F.; Lin, K.H.; Wu, L.Y.; Yu, P.H. Absorptive capacity and autonomous R&D climate roles in firm innovation. *J. Bus. Res.* **2015**, *68*, 87–94.
60. Liu, J.; Cao, J.; Zhang, J.Y. Exclusive or shared? R&D internationalization and firm innovation value capture: Evidence from patent citation data of listed firms. *Int. Trade Issues* **2022**, *477*, 157–174.
61. Zhang, J.; Zheng, W.P. Has the innovation catch-up strategy inhibited patent quality in China? *Econ. Res.* **2018**, *53*, 28–41.