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Digital transformation and the quality of green innovation in manufacturing companies

-- Chain mediation effects based on supply and demand sides

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Abstract: The digital economy has given rise to the digital transformation of enterprises, supply chain management welcomes new opportunities, and the contradiction between economic development and resources, energy and environment needs to be solved urgently. This paper takes China's Shanghai and Shenzhen A-share listed companies in the manufacturing industry from 2010 to 2022 as a sample, and adopts Python crawler technology, SA index, and two-way fixed model to construct a green innovation evaluation system, and builds a mediation effect model with "supply side optimization-demand side pull" as a chain to explore the influence mechanism of digital transformation on the quality of enterprises' green innovation. Explore the influence mechanism of digital transformation on the quality of green innovation of enterprises. A two-way fixed model is used to test the moderating effects of environmental regulation, media attention and the heterogeneity between supply and demand. Finally, suggestions for green innovation of enterprises in the perspective of digital economy are proposed.

Keywords: Digital transformation, Green innovation, Supply and demand sides, Chain mediation effect.

1. Introduction

The 20th Party Congress stated that China's manufacturing industry ranks first in the world. As China's pillar industry and an important vehicle for the construction of a strong nation, the manufacturing sector plays an important role in driving China's national economy, and is also the main force behind carbon emission reduction and green transformation and upgrading of the economy.2024 The government work report explicitly proposed that China should "strengthen the construction of ecological civilization, and push forward the development of green and low-carbon development". In 2020, President Xi Jinping delivered an important speech at the general debate of the 75th United Nations General Assembly, announcing that he would achieve carbon peak by 2030 and strive to achieve carbon neutrality by 2060, reflecting the confidence and determination of the state and government in environmental protection. It can be seen that the impact of enterprises on the environment is not only a key concern for the green transformation of the economy and society, but also an inevitable choice for them to comply with the national green development strategy. However, China's annual carbon dioxide emissions of more than 6 billion tons, ranking first in the world, the Chinese government in the reduction of greenhouse gas emissions by unprecedented international pressure; at the same time, the manufacturing industry is the main field of carbon emissions, accounting for 1/4 of the global carbon emissions. therefore, we want to achieve the "dual-carbon" goal or speed up the construction of enterprise ESG, the green transformation of the manufacturing industry in the era of environmental protection. Therefore, if we want to realize the goal of "double carbon" or accelerate the ESG construction of enterprises, the green transformation of manufacturing industry should not be delayed in the environmental protection era.

With the arrival of the digital economy era, enterprise digital transformation has brought new opportunities for the efficiency and resilience management of upstream and downstream supply chains. In recent years, China has attached great importance to the development of digital technology, promoting enterprise digital transformation in all aspects, and realizing the integration of the digital economy and the real industry. The 2023 China Enterprise Digital Transformation Index points out that it is necessary to take a global perspective, construct a digital core, and achieve business agility and technical resilience. Enterprise digitalization refers to the use of artificial intelligence, virtual reality, big data and other emerging science and technology industries to reform the existing production and operation mode of enterprises, improve production efficiency while reducing production costs, and quickly produce products with performance that meets the needs of customers, so as to achieve industrial upgrading relying on mathematical technology.

The research in this paper specifically makes the following contributions: first, based on the social network analysis method, it explores the quality of the digital economy on the green transformation of enterprises from the supply chain, which expands new research perspectives for enterprise green innovation. Most of the existing studies focus on micro-level innovation within enterprises, and few explore the innovation effect of digitalization and its impact on corporate environmental responsibility from the macro supply chain level. Second, based on the textual analysis method, it explores the influence mechanism of the supply and demand bilateral chain relationship on the green transformation of enterprises empowered by the digital economy, which provides ideas and rationale for how enterprises can alleviate the imbalance of supply and demand in the transformation, and enriches the economic consequences of digitalization of enterprises to a certain extent. Previous scholars have mainly analyzed the economic consequences of digital transformation from the aspects of innovation ability, enterprise performance, and capital market response, but have not yet linked digital transformation to the supply and demand chain effect, and failed to reach a consensus on the effect of

its transformation. Third, in order to study the relationship between digitalization and low-carbon transformation, this paper selects environmental regulation and media attention as two moderating variables based on Porter's hypothesis, and explores the moderating roles of internal environmental protection inputs and the number of external reports in the relationship between digitalization transformation and enterprises' green technological innovations, so as to provide insights on the establishment of greening systems in government departments and the regulation of green innovations in media. By taking environmental regulation and media attention as the two moderating variables, we explore the role of internal environmental inputs and the amount of external reports in regulating digital transformation and corporate green technological innovations, which will have a significant effect on the government's establishment of a greening system and the media's regulation of green innovation quality.

Based on this, this paper starts from factors such as supply-side factor endowment and demand-side business environment, studies the influence of flexible production mode and enterprise scope economy on the effect of enterprise green innovation, explores the relationship between the degree of digital transformation of manufacturing enterprises and the quality of green innovation, realizes the balanced development path choice of enterprise greening reform supply and demand in the new period, and provides scientific theoretical basis for the formulation of regional enterprise green innovation regulation policy.

2. Theoretical Analysis and Research Hypothesis

2.1. Digitalization and Corporate Green Innovation

To achieve the goal of high-quality development in the era of big data, enterprises need to move away from the traditional mindset of realizing production at the expense of the surrounding environment, and instead use emerging digital technologies to comply with green development strategies. First, digital transformation can help companies reduce energy losses and improve efficiency. Through the application of digital technology, enterprises can monitor and manage energy use in real time, identify and solve energy waste problems, and thus effectively reduce energy consumption. For example, using big data analysis technology, enterprises can optimize the production process, reduce energy waste, improve production efficiency and achieve green production. Second, digital transformation helps optimize the human capital structure of enterprises and strengthen the spillover effect of knowledge. In the process of digital transformation, enterprises can improve the level of digital skills of employees and stimulate their innovation potential through training and introduction of talents. At the same time, digital transformation also promotes the sharing and dissemination of knowledge, strengthens the communication and exchange of knowledge within the enterprise, and thus enhances the enterprise's innovative ability and competitiveness. Third, digital transformation can reduce the consumption of resources brought about by information asymmetry and make it easier for enterprises to access innovation resources in the value network. Through digital technology, enterprises can acquire and analyze market information more accurately, reduce the risks associated with information asymmetry, and avoid waste and loss of resources. At the same time, digital transformation also helps enterprises to establish closer cooperative relationships in the value network, obtain more innovative resources and promote the development of green innovation in enterprises.

In summary, digital transformation has an important role in promoting enterprise green innovation, which can help enterprises achieve energy saving and efficiency improvement, optimize the human capital structure and strengthen the spillover effect of knowledge, reduce the resource consumption brought by information asymmetry, so as to promote the enterprise to move towards the green development strategy and achieve the goal of high-quality development. Based on the above theoretical analysis, this paper puts forward the following hypotheses:

H1: Digital transformation of firms can contribute to the quality of green innovation in firms.

2.2. Intermediation of Supply-Side Optimization

The supply-side mediation of green innovation is mainly reflected in the development of digital technology, which improves production efficiency, reduces production costs and promotes the development and application of green technologies. Through digital technology, enterprises are able to better monitor and manage resource utilization and achieve effective use and conservation of resources. Digital technology also facilitates cooperation and information-sharing among enterprises and accelerates the diffusion and application of green innovations.

First, the flexible production method driven by digital technology realizes "flexible production", which improves the quality of green innovation through resource flexibility and organizational flexibility. This flexible production method reduces inventory levels and improves demand response speed, which in turn improves the stability of production and supply. Enterprises are able to quickly and inexpensively adjust production processes, techniques and product types, efficiently reconfigure internal resources, and realize efficient and accurate matching of production capacity and shortened delivery cycles.

Secondly, the application of digital technology and intelligent transformation enables enterprises to more accurately observe the pain points and blockages in production and operation in the green transformation, and then optimize the use of resources, reorganize the production process, and realize the fine management of the whole life cycle of products. Such precise management can effectively improve production efficiency, reduce production costs and promote the development and application of green technologies.

Again, the development of supply networks and platform ecosystems promotes enterprises to improve the dynamic release capacity of external resources (Sun Xinbo et al., 2019). With the supply network and platform ecosystem, enterprises can interact with other stakeholders to share resources, and on the basis of changes in the external environment, realize existing resources and dispose of idle resources by temporarily transferring the right of use and other means. At the same time, enterprises are able to further activate and integrate high-quality external resources, change the way of controlling resources, operate more asset-light, and better adapt to changes in market demand and environmental uncertainty (Li et al., 2019). These measures help to improve

the flexibility and adaptability of enterprises, thus promoting the development of green innovation.

H2: From the supply side, digitalization advances the green transformation by empowering enterprise-wide economies.

2.3. Intermediation of Demand-Side Pulls

The demand-side mediation of green innovation is mainly manifested in consumers' growing concern for environmental protection and sustainable development. As consumer demand for green products and services increases, the application of digital technology provides more information transparency, helping consumers to understand the production process and environmental performance of products, which in turn influences their purchasing decisions. This increased consumer demand will further push companies to invest more in green innovation, thereby facilitating the generation and application of green innovations.

The widespread use of digital technology has given rise to green market value openings in the new business landscape, and has also contributed to the enhancement of enterprises' cross-border business capabilities. Through digital transformation, enterprises are able to better understand and meet the diversified needs of consumers, thus pushing selected content and increasing their chances of purchasing green products. At the same time, digital technology provides more information transparency and helps consumers understand the production process and environmental performance of products, further enhancing their trust and preference for green products.

Based on the 4Cs marketing theory (Robert Lauterborn, 1990), the demand-driven matching model enables products to better satisfy the diversified needs of consumers, which in turn increases their chances of purchasing green products. The application of big data technology enables enterprises to gather customer needs more quickly and accordingly provide service-oriented products that respond to customer needs in a timely manner, which further enhances customer satisfaction.

In addition, the development of intelligent service platforms has enabled enterprises to better provide value-added services to their customers and to expand services such as consulting, maintenance, sharing, research and development, and leasing under the digital business model, thus facilitating a closer connection between supply and demand. This transformation not only meets consumer demand for green products, but also reduces resource consumption and pollution emissions at the physical contact level, helping to drive the shift towards green innovation.

H3: From the demand side, digitalization advances the green transition by empowering the enterprise-wide economy.

2.4. Intermediation of Supply and Demand Bilateral Chains

The chain mediation between digital transformation and green innovation is not only reflected on the supply side, but also has an impact on the demand side. From the supply side, the application of digital technology can significantly improve the productivity and resource utilization efficiency of the manufacturing industry. Through the application of digital technology, enterprises can realize the intelligence and automation of the production process, optimize the production process, reduce the waste of resources and lower production costs. This improvement in production efficiency and resource utilization efficiency will directly promote the supply of green products. Digital transformation not only improves the production efficiency of green products, but also promotes the research and development and innovation of green products, thus increasing the supply of green products.

On the other hand, digital technology is also having an impact on the demand side, guiding consumer demand for green products. As society's concern for environmental protection and sustainable development continues to grow, so does consumer demand for green products. Digital technology provides consumers with more information transparency and helps them understand the production process and environmental performance of products, thus influencing their purchasing decisions. Through information delivery and customized services, digital technologies can stimulate consumer demand for green products and further promote green innovation.

Under this chain relationship between supply and demand, the mediating role between digital transformation and green innovation is reflected. Digital transformation provides sufficient digital elements for the supply side, improves production efficiency and innovation capacity, and thus promotes the supply of green products; at the same time, digital technology also indirectly promotes the development of green innovation by guiding consumer demand for green products. Therefore, a chain intermediary role is formed between digital transformation and green innovation, which together promote the transformation and upgrading of manufacturing to green development.

H4: Supply-side optimization and demand-side pull act as chain mediators between digitalization and green transformation and upgrading of enterprises.

2.5. Interactive Effects of Digitization and Environmental Regulation

The interaction effect of digitalization and environmental regulation plays an important role in the green transformation of enterprises, which can be analyzed in depth by combining the theories of Porter's hypothesis and neoclassical economics. First of all, Porter's hypothesis (Poter and Linde, 1995) [29] argues that reasonable environmental regulation facilitates enterprises to carry out innovative activities, and leads to the enhancement of enterprise productivity through technological innovation, which in turn promotes the long-term economic growth of enterprises. In this framework, the development of digital technology provides enterprises with more innovative possibilities. Through digital technology, enterprises can realize the refined management of resources and intelligent control of production processes, thus improving productivity, reducing costs and promoting the development and application of green technologies. In addition, digital technology creates new business models and market opportunities for enterprises, making it easier for them to adapt to the requirements of environmental regulations and promoting green transformation.

However, neoclassical economics suggests possible negative effects of environmental regulation. According to the theory, environmental regulation increases the production costs of enterprises (Xin Zhang, 2022), reduces their competitiveness, crowds out R & D investment, and is not conducive to capital turnover and green technology innovation. In this case, digital transformation can be a coping strategy. Through digital technology, enterprises can optimize the production process, improve resource utilization efficiency, and reduce costs, so as to alleviate the pressure brought by environmental regulations and achieve green

transformation.

Therefore, the interaction effect between digitalization and environmental regulation can be understood as a two-way relationship. On the one hand, the development of digital technology can make up for the inadequacy of environmental regulation, facilitate the implementation and enforcement of environmental regulation, and promote the development of enterprises in the direction of green transformation. On the other hand, the strengthening of environmental regulation will also prompt enterprises to increase their efforts in digital transformation to adapt to environmental changes and realize green development. Considering the Porter's hypothesis and neoclassical economics, it can be concluded that digitalization and environmental regulation synergistically promote the green transformation of enterprises.

H5: Digitalization and environmental regulation synergies for corporate green transformation.

2.6. The Moderating Effect of Media Attention in Digitalization on Firm Innovation

The role of the media in digitalization on enterprise innovation can be reflected as both a bystander and an enabler. As a bystander, the media is not directly involved in the digital transformation process of an enterprise at the initial stage, but when digital transformation attracts public attention, the exposure of media coverage becomes an important factor in driving the transformation of an enterprise. Media reports can influence the public's judgment, which in turn prompts enterprises to accelerate the pace of digital transformation, especially in terms of green innovation. Second, according to the media governance effect, when media attention reaches a certain level, society will force enterprises to be responsible for the environment by triggering the reputation effect mechanism, thus enhancing their carbon emission reduction capability. Continuous media attention can shape the social image of enterprises, push them to pay more attention to environmental protection and sustainable development, and promote the enhancement of their green innovation. However, expanding media exposure can be counterproductive. Excessive media exposure can lead to negative effects. For example, excessive public pressure or negative publicity may cause companies to adopt a conservative attitude towards innovation, or even affect the pace of their digital transformation.

In summary, media has an important moderating effect in digitalization on corporate innovation. Reasonable media attention can push enterprises to accelerate digital transformation and green innovation, enhance their awareness of environmental responsibility and social image, and thus promote their sustainable development. However, excessive media exposure may produce negative effects and affect the innovation decisions and behaviors of enterprises, and thus needs to be moderately managed and controlled.

H6: Media attention has a moderating effect in the impact of digitalization on firm innovation

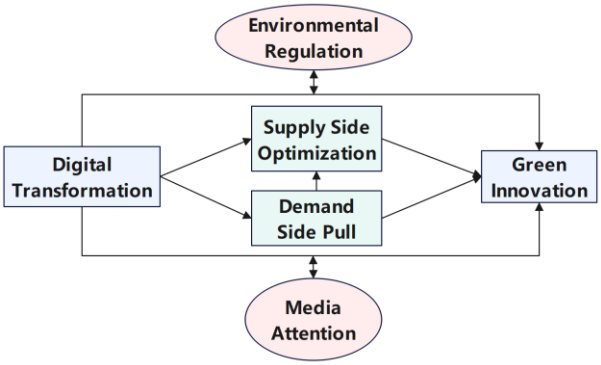

Figure 1. Theoretical model

3. Study Design

3.1. Selection of the Study Sample

This paper takes A-share manufacturing companies listed in Shanghai and Shenzhen from 2010 to 2021 as the research sample, in which the annual report data comes from Juchao Information Network, green patent and media concern data comes from China Research Data Platform (CNRDS), environmental regulation data comes from China Statistical Yearbook, China Urban Statistical Yearbook, China Environmental Statistical Yearbook, and the rest of the enterprise Characterization data are obtained from the iFinD database and the CSMAR database. In this paper, the sample data are processed as follows: (1) ST and PT companies are excluded; (2) companies with key missing values in the financial data are excluded; and (3) to avoid the influence of extreme values, continuous variables are subjected to shrinking of the upper and lower 1%. The final screening obtained 9,800 data samples, which were processed and analyzed using Excel 2016 and Stata17.0.

3.2. Modeling

In order to investigate the direct impact of digital transformation intensity on the quality of green innovation in manufacturing companies, this paper constructs Model 1:

$$\mathrm{Gpatent}_{i,t} = \beta_0 + \beta_1 \mathrm{Digword}_{i,t} + \sum_m \beta_m \mathrm{Controls}_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where i and t denote firms and years, respectively, $\mathrm{Gpatent}_{i,t}$ denotes the green innovation quality of firm i in year t, $\mathrm{Digword}_{i,t}$ denotes the intensity of digital transformation of firm i in year t, $\mathrm{Controls}_{i,t}$ denotes the set of control variables, and $\varepsilon_{i,t}$ is the random error term.

Based on the regression model (1), the mediation model is constructed to validate H2 and H3, as in equation (2) (3):

$$Mediator_{i,t} = \beta_0 + \beta_1 Digword_{i,t} + \sum_m \beta_m \mathrm{Controls}_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$\mathrm{Gpatent}_{i,t} = \beta_0 + \beta_1 Digword_{i,t} + \beta_2 Mediator_{i,t} + \sum_m \beta_m \mathrm{Controls}_{i,t} + \varepsilon_{i,t} \quad (3)$$

Equation (2) is the regression model of the explanatory variable Digword on the mediator variable Mediator, and equation (3) is the regression model of the mediator variables Mediator and Digword on the explanatory variable Gpatent. Where Mediator denotes the value of mediating variable of enterprise i in year t, which specifically includes supply-side flexible production method FPM and demand-side enterprise-wide economy EOS, and the definition of the rest of the variables is the same as equation (1).

Further, referring to the study of Fang Jie et al, the chain mediation effect model is constructed to verify H4 on the basis of Eq. (1)(2) as Eq. (4)(5).

$$FRM_{i,t} = \beta_0 + \beta_1 Digword_{i,t} + \beta_2 EOS_{i,t} + \sum_m \beta_m \text{Controls}_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$\text{Gpatent}_{i,t} = \beta_0 + \beta_1 Digword_{i,t} + \beta_2 EOS_{i,t} + \beta_3 FRM_{i,t} + \sum_m \beta_m \text{Controls}_{i,t} + \varepsilon_{i,t} \quad (5)$$

Finally, the moderating variable Moderator and the interaction term between the moderating variable and digitization (Digword×Moderator) are included in the basis of equation (1) to test H5 and H6, as in equation (6). Where $\text{Moderator}_{i,t}$ denotes the value of the moderating variable of enterprise i in year t, specifically including environmental regulation ER and media attention Media, and the rest of the variables are defined in the same way as equation (1).

$$\text{Gpatent}_{i,t} = \beta_0 + \beta_1 \text{Digword}_{i,t} + \beta_2 Moderator_{i,t} + \beta_3 (\text{Digword} \times Moderator)_{i,t} + \sum_m \beta_m \text{Controls}_{i,t} + \varepsilon_{i,t} \quad (6)$$

3.3. Definition of Variables

3.3.1. Explained Variables

Green Innovation Quality (Gpatent) of Manufacturing Enterprises. This paper draws on the research of Lianchao Yu et al. and uses the data obtained from the China Research Data Service Platform (CNRDS), i.e., it measures the degree of green transformation of enterprises by adding 1 to the number of green invention patent applications of listed enterprises and then taking the natural logarithm.

3.3.2. Explanatory Variables

Digital Transformation Intensity (Digword). Based on the machine learning method, Python is used to text mine the information involving digital development in the annual reports of listed companies. The specific method is to use the digital transformation data obtained from the Cathay Pacific database (CSMAR), i.e., take the frequency number of words containing five types of characteristics such as artificial intelligence technology, blockchain technology, cloud computing technology, big data technology, and the use of digital technology appearing in the financial statements and add 1 and then take the natural logarithm, and ultimately get the green transformation indicator.

$$Digword = \ln(1 + \frac{Total\ frequency\ of\ digital\ transformation\ keywords\ in\ financial\ statements}{Total\ number\ of\ words\ in\ financial\ statements}) \quad (7)$$

3.3.3. Mediating Variables

Supply-side flexible production method (FPM). Drawing on Zhou Zegong et al. (2020), principal component analysis is used to construct a comprehensive indicator of asset-light operation as a proxy variable for the flexible production of enterprises.

Demand-side enterprise economies of scope (EOS). The variable enterprise scope economy selects the index of diversification degree as the measurement variable of enterprises' cross-border business expansion into new areas. Specifically drawing on existing research, the Herfindel index is constructed for the industry to which the main business belongs, with the special note that the larger the index is, the lower the degree of diversification of the enterprise is.

3.3.4. Moderating Variables

Environmental Regulation (ER). In order to avoid the bias caused by a single indicator on the regression results, this paper refers to Ren et al. (2020), and selects three pollution emission indicators of industrial wastewater, industrial SO2 and industrial soot in each province in 2010-2021, and utilizes the entropy value method to construct the composite index of environmental regulation required in this paper. Due to the lack of statistical data of some counties and cities, this paper uses the composite index of intensity of prefecture-level cities as a substitute.

Media attention (Media). Selected with reference to scholars such as Wen Su-Bin and Zhou Li-Liu and Ou Jin-Wen, it mainly covers online media and newspaper media coverage.

3.3.5. Control Variables

To mitigate the impact of omitted variables on the results, the following control variables are selected: firm size (Size), firm age (Age), firm growth (TobinQ), return on assets (ROA), gearing (Lev), nature of firm ownership (SOE), equity concentration (Top1), institutional shareholding (Institution), board of directors independence (Ind), research and development intensity (R & D), and regional economic development level (GDP). The definitions of the specific variables are shown in Table 1.

Table 1. Description and definition of variables

Variable type	Variable Name	Variable Symbol	Define
Explanatory Variable	Quality of green innovation in business	Gpatent	ln(1+ Number of green invention patent applications)
Explanatory Variable	Intensity of digital transformation	Digword	Text mining of corporate annual reports using Python
Intermediary Variable	Supply-side flexible production methods	FPM	Asset-light operating index (net intangible assets/long-term assets)
	Demand-side firm economies of scope	EOS	Indicator of the degree of diversification (Herfindel index of the industry to which the main business belongs)
Moderator Variable	Environmental regulation	ER	Composite index of environmental regulation
	Media attention	Media	Total media coverage/1000
Control Variable	Enterprise size	Size	Ln (total assets)
	Age of business	Age	Ln (time of establishment of the enterprise)
	Corporate Growth	TobinQ	Enterprise market value/total book assets
	Return on assets	ROA	Net assets/total assets
	Gearing	Lev	Total liabilities/total assets
	Nature of business ownership	SOE	1 for state-owned enterprises, 0 for non-state-owned enterprises
	Shareholding concentration	Top1	Shareholding ratio of the largest shareholder
	Institutional holdings	Institution	Sum of institutional investors' shareholdings
	Board independence	Ind	Number of independent directors / Number of directors
	R&D intensity	R&D	R&D investment/revenue of listed manufacturing companies
	Level of regional economic development	GDP	Ln (GDP per capita in the region where the firm is located)

4. Endogeneity and Robustness Tests

4.1. Endogeneity Test

Propensity Score Matching (PSM) method. In order to mitigate the endogeneity problem that may arise from sample self-selection, the PSM method is used in this paper for robustness testing.The OLS estimation suffers from the drawback that it may be interfered by issues such as self-selection bias, i.e., firms that are actively engaged in digital transformation may themselves place more emphasis on solving supply chain problems. Therefore, PSM estimation can be used to address the above issues. Three methods of nearest-neighbor matching, radius matching, and kernel matching were used to match the samples and regress them, and the results are shown in Table 4.The regression coefficients of digitization are still significantly positive under a variety of matching principles, suggesting that the findings are still robust even after considering the sample self-selection problem.

Instrumental variable approach (IV). Considering that there may be a bidirectional causality problem between digital transformation and firms' green innovation performance, i.e., due to the fact that the more successful the quality of firms' green innovations is, the more likely it will increase the firms' demand for, for example, digital technologies and thus their willingness to carry out digital transformation more strongly. Therefore, this paper refers to the approach of Xinyu Tu and Xiaoling Yan (2022) to regress Digword lagged by one period as an instrumental variable (L.Digword). The first top ten cities in the White Paper on Digital Economy Index of Chinese Cities are defined as 1, and other cities are defined as 0, to construct a dummy variable for the level of urban digital economy development. Theoretically, the regional digital information infrastructure and development level will promote the digital transformation of enterprises in the jurisdiction to a certain extent, i.e., the above two indicators are highly correlated with the digitalization level of enterprises, while not directly affecting the quality of green innovation of enterprises, which is in line with the basic conditions of instrumental variable selection. In addition, the p-values of Sargan test are all greater than 0.1, and the minimum eigenvalues are all greater than the critical value of 10, so the instrumental variables selected in this paper are reasonable and effective.

4.2. Robustness Tests

Replacement of core explanatory variables. This paper uses the digital transformation indicator (Digital_W) constructed by Wu Fei et al. (2021) based on Python text extraction of annual reports of listed companies, replacing the digital transformation indicator (Digword) from the Cathay Pacific database used in the benchmark regression model for the regression. As can be seen from Table 5, the findings of this paper still hold after this robustness test.

Extending the time window. The green innovation quality improvement process of enterprises is not a one-step process, and the accumulation of green innovation advantages in the early stage will inevitably affect the results of their green innovation quality improvement in the later stage. Therefore, this paper adopts the dynamic panel estimation method considering the time delay to re-perform the above test. Considering that there may be a lag in the actual effect of digitization on the green transformation of enterprises, the explanatory variables (Digword) are delayed backward in time by 2-4 periods, and then the delayed variables are used as the explanatory variables for regression analysis. Models M12 to M14 are three different regression models using different number of lags for investigating the impact of lagged effects of explanatory variables on dependent variables. The results show that the findings of the study are still validated after the aforementioned robustness tests, confirming that the

findings of this paper have robustness and long-term effects.

5. Study on the Mechanism of Influence of both Supply and Demand

This study adopts a difference-in-difference (DID) analytic design (DID) approach, aiming to investigate the impact of the degree of digital transformation of enterprises on the quality of green innovation under the differences in factor endowments on the supply side and the differences in business environments on the demand side. We grouped our sample based on the factor intensity of the manufacturing industry and the information infrastructure index of the province. First, we subdivided the sample into labor-intensive, capital-intensive, and technology-intensive industries based on the factor intensity of the manufacturing industries in which they are located, and examined the impact of digitization on the quality of green innovation of manufacturing firms in these industries, respectively. Second, we group the samples based on the information infrastructure index of the host province.

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