The Impact of the Digital Economy on the High-Quality Development of Green Marketing in China's Manufacturing Industry: Applications of the Spatial Durbin Model

Jing Li[1], Yan Shen[2], Lili Sun[3], Tao Sun[4]*

[1]Shandong Vocational and Technical University of International Studies, Rizhao, Shandong, China
https://orcid.org/0009-0003-1557-4955
[2]Guangdong Songshan Polytechnic, Shaoguan, Guangdong, China
https://orcid.org/0009-0003-7294-5142
[3]Shandong Vocational and Technical University of International Studies, Rizhao, Shandong, China
https://orcid.org/0009-0000-6396-0023
[4]Shandong Vocational and Technical University of International Studies, Rizhao, Shandong, China
https://orcid.org/0000-0003-3121-2340

*corresponding author's e-mail: nuaastao@163.com

Graphical abstract
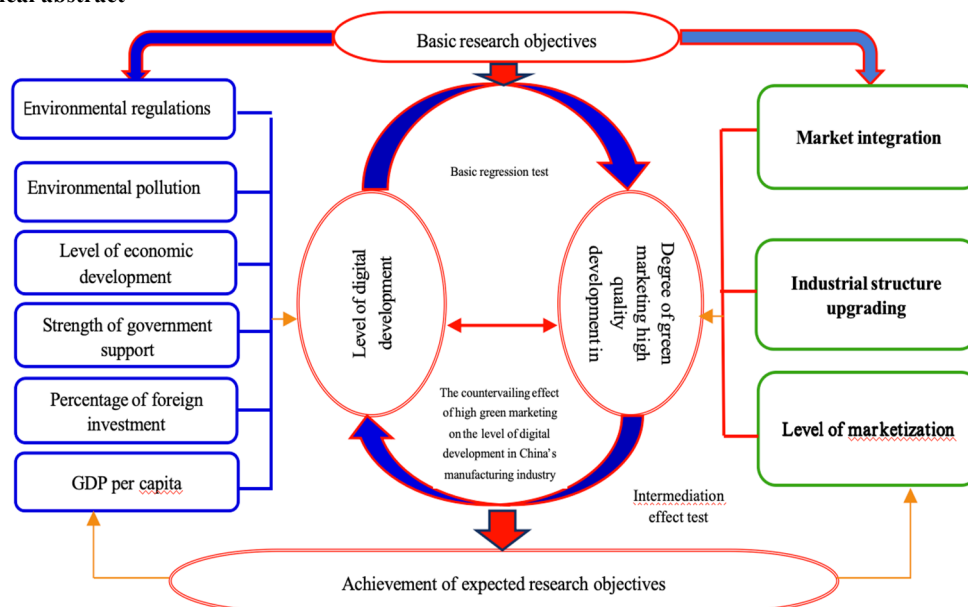
Abstract: The digital economy provides China's manufacturing industry with a pathway to establish new national competitive advantages and is an essential driving force for the high-quality advancement of green marketing. Utilizing data from 30 Chinese provinces from 2013 to 2022, this study employs the spatial Durbin model to investigate the spatial relationship between the digital economy and the advancement of green marketing at a high quality. The findings indicate that the growth of the digital economy significantly fosters high-quality development in green marketing and exhibits positive spatial spillover effects on neighboring regions. The Application of spatial Durbin regression to multi-province areas has revealed that the more economically developed the region, significantly influences of the digital economy on the high-quality development of green marketing, with a local siphoning phenomenon currently visible in the eastern region. The western region exhibits a spatially positive spillover effect from the high-quality development of green marketing in other regions. Furthermore, developing the digital economy in neighboring regions significantly enhances the high-quality development of green marketing in this region. The findings remain stable when evaluated using the alternative variables method and the control fixed effects approach.

Keywords: digital economy, green marketing quality development, Spatial Durbin model, Spatial spillovers

1. Introduction

China's 14th Five-Year Plan, drafted in 2020 and encompassing the period from 2021 to 2025, strongly emphasizes high-quality development. Central to this agenda are the "dual-carbon" objectives of achieving peak carbon emissions by 2030 and attaining carbon neutrality by 2060. Consequently, "green development" has emerged as a key industrial priority. Regarding energy consumption and pollution emissions, there is an urgent need to accelerate the development of low-carbon production methods while enhancing industrial efficiency. The burgeoning digital economy presents new opportunities for China's manufacturing sector in the

realms of digitalization, artificial intelligence, and green transformation. The Global Digital Economy White Paper (2023), published by the China Academy of Information and Communications Technology (CAICT), hereinafter referred to as the "White Paper," indicates that the development of the digital economy in major countries continues to accelerate. China's digital economy has experienced an average annual compound growth rate of 14.2%. In 2024, the National People's Congress reaffirmed its commitment to "strengthening scientific and technological innovation and building a modernized industrial system" to create new advantages within the digital economy. This initiative seeks to fully leverage vast data resources and diverse application scenarios while promoting a deeper integration of digital technology into the real economy. As a novel type of production factor, data serves as the foundation for digitalization, networking, and artificial intelligence. The advancement and commodification of data represent a significant indicator of technological progress within the digital economy. In this context, green marketing can facilitate the transition from production to marketing processes toward sustainability while optimizing resource utilization through advanced digital technologies such as the Internet, big data, and artificial intelligence. Integrating digital technology into the domains of green marketing and high-quality development enhances production efficiency within the manufacturing sector, thereby diminishing resource consumption and mitigating environmental pollution. At the same time, the digital economy facilitates market integration, enhances industrial structure, and offers manufacturing enterprises a broader array of channels for market development and brand promotion. Leveraging e-commerce, social media, and various other platforms enables precision marketing and customization, thereby enhancing added value and improving market competitiveness. To promote green manufacturing and elevate the quality of the Chinese manufacturing sector, it is particularly urgent to investigate the impact of the digital economy on the evolution of green marketing. This includes clarifying their interrelationship and defining existing constraints.

The existing literature examines the impact of the digital economy from micro, meso, and macro perspectives. At the micro level, the digital economy facilitates enterprises in achieving economies of scale and scope by enhancing the efficiency of innovative resource allocation, transforming production methods and business models, and fostering balanced supply-demand development through rapid and precise matching mechanisms. Wang et al. (2023) highlight changes in production means and an increase in new factors of production as critical characteristics that differentiate the digital economy from traditional economic frameworks. At the meso level, the digital economy broadens industrial associations via the advantages of digital platforms. It continuously generates new industries and business models through industrial innovation and integration, promotes digitization within traditional sectors, and propels upgrades to industrial structures. Ma et al. (2022) posit that the digital economy and upgrades in industrial structure exhibit spatial autocorrelation, with the former significantly facilitating the latter. The digital economy stimulates economic growth at a macro level by enhancing social productivity and resource allocation efficiency. Furthermore, it fosters green and high-quality development by improving total factor productivity. Wei and Hou (2022) argue that the digital economy can significantly promote urban green development; however, they also note the presence of heterogeneity and time lags in this process. Furthermore, additional factors such as industry scale and infrastructure development will influence the dividend effects of the digital economy. According to Xue and Wang (2006), critical elements contributing to the "digital divide" include the status of information resources, human resource structure, investment in research and development, and levels of economic development.

The research on the green and high-quality development of the manufacturing industry in the digital economy mainly focuses on two aspects: how to measure the level of development and influencing factors. Concerning the former, scholars have mostly adopted the stochastic frontier model and the improvement methods of data envelopment analysis. Li et al. (2022) constructed a supply-demand model of China's industrial pollution emissions and measured China's industrial green development level. Zhou (2023) posits that the digital economy can facilitate the green development of the manufacturing sector through technological innovation and spatial spillover effects, with a pronounced influence characterized by a gradient of "high in the east and low in the west". Based on the dynamic spatial Durbin model, Zhang (2024) asserts that the digital economy exerts a significant positive impact on high-quality regional green development, which is progressively amplified over time; notably, its long-term effects surpass those observed in the short term. Consequently, it is imperative to commit to a trajectory of green and high-quality development by accelerating advancements in the digital economy, enhancing human capital levels, and promoting new urbanization initiatives to achieve sustainable green growth alongside robust and enduring progress within the digital economy. The impact factors of the digital economy on the green and high-quality development of the manufacturing industry. Zhao and Shi (2021) identify green and high-quality development as encompassing two key dimensions: Firstly, a process dimension that emphasizes the production and operational efficiency across each industrial chain link. This involves reducing and optimizing factor inputs, enhancing energy utilization efficiency, and minimizing adverse impacts on the ecological environment to the greatest extent possible. Secondly, a result dimension

that focuses on both the quality and quantity of product supply, alongside optimizing and upgrading industrial structures. Matthess et al. (2023) proposed that the deep integration of digital technology with the manufacturing industry can enhance connectivity among all production links within this sector. This integration optimizes energy production and consumption methods, thereby achieving energy-saving effects and promoting sustainable development in the manufacturing industry. Manesh et al. (2021) posited that from the perspective of technological innovation, advancements in the digital economy can enhance enterprises' innovative capabilities and facilitate manufacturing firms in executing innovation activities. By transcending spatial-temporal barriers at each stage of innovation it fosters open access to innovative resources. Ultimately, this promotes innovations in both production processes and products, enabling innovative enterprises and their stakeholders to achieve sustainable development while enhancing the market's innovation ecosystem. Heo and Lee (2019) highlighted a significant correlation between digitalization and upgrading industrial structures, emphasizing this relationship from the perspective of industrial structure enhancement. The development of the digital economy, along with its integration into other industries, catalyzes innovation and structural advancement within various sectors. Consequently, the role of data in facilitating these upgrades is becoming increasingly critical. Wang and Han (2024) suggested that improvements in digital infrastructure, advancements in both digital industrialization and industrial digitalization, as well as enhancements to the digital economic environment would foster green and high-quality development within the manufacturing sector.

Research on green marketing has primarily focused on its effects on consumers and society and the influence of digital technology within this domain. Huang and Zhou (2024) conclude that both environmental concerns and green marketing exert significant positive impacts on consumers' intentions to make green purchases. Furthermore, they identify that factors such as green brand image, eco-friendly products, and recycling initiatives mediate the relationship between environmental concerns and these purchase intentions. Mu (2024) emphasizes that effective green marketing strategies can not only cultivate an enterprise's environmental reputation but also enhance its perception of social responsibility, which subsequently leads to improved sales performance. Sui et al. (2015) and others conceptualize green marketing as a means of promoting the adoption of sustainable technologies or facilitating the development of innovative eco-friendly products. Promoting such technologies, products, and related marketing services is expected to advance the coordinated growth of economic efficiency while simultaneously fostering environmental protection and resource conservation – thereby effectively addressing the needs of suppliers, consumers, and other stakeholders. Oseremen (2019) pointed out that product innovation and corporate social responsibility had a negative and significant relationship with competitive advantage, while environmental commitment was significant and positively related to competitive advantage. In addition, companies should embark on product innovation at regular intervals aimed at adding environmental features to products, rebuilding, and repackaging. Finally, firms should, in a matter of urgency, improve their corporate social responsibility in the environment where they operate. Li et al. (2021) assert that digital product innovation negatively affects green marketing performance within the manufacturing sector; conversely, they find that digital process innovation has a positive impact, with absorptive capacity acting as a negative moderating factor. Additionally, they report that digital service innovation also exerts a negative influence, although the moderating effect of absorptive capacity is not statistically significant. In addition, Danish et al. (2021) proposed that the development of green marketing within Indian manufacturing should prioritize environmental concerns, green promotional initiatives, customer trust in green products, and the challenges associated with green marketing. Consequently, they emphasize that businesses ought to perceive environmental protection as a market opportunity, advocating for integrating green marketing as a standard practice for sustainable development.

To summarize, research examining the impact of the digital economy on the high-quality development of green marketing within the Chinese manufacturing sector remains in its nascent stages. Existing studies predominantly concentrate on performance, structure, and innovation. There is a notable scarcity of scholarly work linking the digital economy to the high-quality development of green marketing in this industry, and investigations into spatial effects between these two domains are even less common. In light of this gap, this paper employs the Spatial Durbin Model to analyze the direct impacts, spatial spillover effects, and regulatory mechanisms through which the digital economy influences high-quality green marketing development within China's manufacturing sector. This analysis is based on measurements that reflect the evolution of China's digital economy from 2012 to 2022. Furthermore, it investigates how market integration and industrial structural upgrades function as moderating factors. The findings aim to provide empirical insights into harnessing digital technology to optimize resource allocation in market-oriented green marketing practices amid a rapidly growing digital economy. Additionally, it seeks to promote regional market integration alongside advancements in industrial structures.

2. Materials and Methods

2.1. Research objects and data sources

To investigate the impact of the digital economy on the high-quality development of green marketing within China's manufacturing sector, this study selected a sample comprising 30 Chinese provinces. The data utilized in this research were sourced from the China Environmental Statistics Yearbook and the China Energy Statistics Yearbook. Specifically, information regarding the digital economy, digital industrialization, and industrial digitization was obtained from various reputable publications, including the China Statistical Yearbook, China Electronic Information Industry Statistical Yearbook, China Industrial Statistical Yearbook, and historical statistical yearbooks for each province or city. Data pertaining to other variables were also derived from the China Statistical Yearbook.

Table 1. Descriptive statistics of variables Descriptive statistics

Index Name	Symbols	Sample capacity	Standard deviation	Min	Max
Digital Economy Development Index	Led	3000	0.402	2.670	0.0798
China Manufacturing Green Marketing High-Quality Development Index	Ghmmi	3000	0.339	1.980	9.1080
Market Integration	Segm	3000	0.748	7.610	11.0500
Industrial Structure Upgrade	Istr	3000	0.089	0.326	0.8360
Environmental Regulation	Even	3000	0.551	6.190	2.4070
Investment in Environmental Pollution Control	Inven	3000	0.220	0.0047	1.0000
Level of Economic Development	Eco	3000	0.871	7.610	11.6100
Government Expenditure Level	Gov	3000	0.115	0.110	0.7870
Percentage of Foreign Investment	Fdi	3000	1.624	7.889	16.687
GDP per capita	Gdp	3000	0.757	6.360	9.6500

The period from 2013 to 2022 was designated as the base timeframe to ensure data consistency. The empirical testing model was developed based on the principle that selected variables must exhibit correlation and should not give rise to covariance phenomena. We aimed to identify core variables that exert a significant influence on the explanatory variables while also taking into account data accessibility. The foundational data for most of these selected variables were derived directly from statistical sources or could be obtained through straightforward calculations.

2.2. Research hypotheses

Promoting the deep integration of the rapidly advancing digital economy with the high-quality development of green marketing in the manufacturing sector is a topic of global interest. The digital economy, characterized by low information acquisition costs, timeliness, and inter-temporal dissemination, may persistently impact the high-quality development of green marketing within the manufacturing industry, potentially leading to spatial spillover effects. This paper will examine how the digital economy influences the high-quality development of green marketing in China's manufacturing sector, particularly emphasizing spatial spillover effects and regulatory mechanisms.

The sustainability, extensive reach, and high permeability of the digital economy significantly contribute to advancing high-quality green marketing within the manufacturing sector. From a macroeconomic perspective, this approach represents a development model characterized by high efficiency, low pollution, minimal waste, as well as green supply chains and effective green marketing communication. The digital economy positions data as the central input element that significantly influences the virtual simulation of various processes, including product design, processing, assembly, and marketing. This approach aims to accelerate the product research and development cycle, reduce the cost structure associated with products, enhance product quality, and optimize the rational allocation of resources. From a micro perspective, developing and applying digital technology can assist high-polluting, high-emission manufacturing enterprises in establishing an intelligent environmental marketing regulatory system while fostering innovation in manufacturing technologies. For instance, digital technology can be employed within the production processes of green technologies to enhance resource utilization and minimize pollutant emissions. Moreover, green marketing services can effectively address the demands of suppliers, consumers, and other stakeholders. Green technologies, products, and services promoting environmental protection and resource conservation can be effectively developed through

various stages, including product development, marketing strategies, and digital technologies and platforms. These approaches enable enterprises to better align with consumer demand for sustainable products. Consequently, companies can sustain their competitive advantage and differentiation while exploring innovative avenues for value creation. The advancement of the digital economy thus plays a crucial role in facilitating the digital transformation of green marketing practices. It accelerates adjustments in manufacturing factor structures and contributes to a reduction in energy consumption within enterprises.

Hypothesis 1: The digital economy has the potential to enhance the development of green marketing and improve the quality of China's manufacturing industry.

The internal logic underlying the upgrading of industrial structures suggests that integrating the digital economy into traditional manufacturing sectors can attract a greater array of innovative resources. This, in turn, facilitates technological advancements within these traditional industries, enhances industrial efficiency and innovation capacity, and further accelerates the digital transformation of conventional manufacturing practices. With the ongoing transformations in global economic patterns and the advancement of technological progress, industrial structures are transitioning from traditional low value-added, high-polluting, and high-energy-consuming sectors to those characterized by high value-added, low-polluting, and low-energy-consuming attributes. From the perspective of optimizing and rationalizing industrial structure, the digital economy primarily fosters a more advanced industrial framework through the deep integration of tertiary industries (Chen et al. 2020). Since it employs digital information as a production factor, its mode of production is comparatively more medium- to high-end than traditional industries (Zhang 2018). The rationalization of the industrial structure is primarily manifested in the tendency of the digital economy to transition production from low technology and low efficiency toward high technology and high efficiency (Li 2019). The extensive adoption of digital technology fosters connections and synergies between secondary and tertiary industries and across horizontal and vertical industry chains, thereby promoting the rationalization of industrial structure (Ding 2020). This rationalization necessitates that manufacturing enterprises continuously adapt their marketing and production strategies in response to fluctuations in market demand. As a marketing approach centered on environmental sustainability, consumer preferences, and the commitment to sustainable development, green marketing is progressively facilitating the transformation and upgrading of the manufacturing sector. A green marketing strategy fosters the research and development, production, and sales of environmentally friendly products to satisfy manufacturing enterprises' requirements for ecological protection as well as healthy and high-quality offerings. This enhances market competitiveness and promotes the green advancement of the entire industrial chain, thereby contributing to the optimization and upgrading of industrial structures. Accordingly, this article proposes the following research hypothesis.

Hypothesis 2: The digital economy may exert a beneficial mediating influence on advancing high-quality green marketing development within the manufacturing sector, facilitated by enhancements to the industrial structure.

The advancement of the digital economy and the growing trend toward marketization have fundamentally transformed the traditional economic paradigm. These two phenomena can be viewed as mutually reinforcing. Decentralized, modern digital technological infrastructures – such as big data, the industrial internet, artificial intelligence, and blockchain – facilitate precise matching and cross-regional flows and circumvent institutional or administrative barriers. This results in an enhanced level of market integration (Chen et al. 2018). In a large, unified market, enterprises are likely to enhance their marketing investments and actively pursue collaborations in marketing technology strategies. This approach allows them to capitalize on competitive advantages within the marketplace, thereby fostering healthy competition and facilitating technology sharing (Li et al. 2020). The heightened level of market integration also permits the digital economy to achieve a broader spectrum of economies of scale. The influence of digitalization on high-quality green marketing within China's manufacturing sector can rapidly extend to adjacent regions, thereby enhancing the incentive effects of green marketing driven by the digital economy and facilitating improvements in overall green marketing capabilities. In light of this, the article posits the following research hypothesis:

Hypothesis 3: The degree of market integration may amplify the effects of the digital economy on high-quality green marketing and generate positive spatial spillover effects.

2.3. Research design

2.3.1. Variable measurement and explanation

Explained Variable: The China Manufacturing Green Marketing High-Quality Development Index (Ghmmi). "Made in China 2025" advocates that, in pursuit of high-quality development, China's manufacturing sector must transition from a competitive advantage rooted in low costs to one founded on quality and efficiency, shifting from factor-driven to innovation-driven methodologies, evolving from traditional manufacturing to green manufacturing practices; and transforming from production-oriented to service-oriented manufacturing. Following these imperatives, this paper establishes a comprehensive index evaluation system encompassing four dimensions – operating profit, marketing revenue, product innovation, and energy consumption – resulting in the formation of four subsystems alongside thirteen measurement indicators (refer to Table 2).

Table 2. Development Index for High-Quality Green Marketing in Manufacturing

First-level indicators	Secondary indicators	Variables	Unit	Targets
Manufacturing green marketing high quality development index	Operating profit	Profitability of main business income of industrial enterprises	%	Positive
		Industrial enterprise assets/average employment/(million/person)	%	Positive
		Value added of manufacturing industry Value added of high-end manufacturing industry	%	Positive
	Marketing revenue	Total marketing revenue	Billions of dollars	Positive
		Sales revenue of new products of industrial enter-prises above designated size	Billions of dollars	Positive
		Sales revenue of new products of high-tech manufacturing industry	Billions of dollars	Positive
	Product innovation	Number of effective invention patents of industrial enterprises	Pieces	Positive
		Number of new product development projects of industrial enterprises above designated size	Pieces	Positive
		Percentage of number of innovators in industrial enterprises above designated size	%	Positive
	Energy consumption	Energy Consumption per Unit of Industry	m^3/ten thousand dollars	Negative
		Regional electric power consumption/national total electric power consumption (Tibet part is missing)	%	Positive
		Generation of general industrial solid waste	%	Positive
		Total industrial wastewater discharge	%	Positive

This article primarily focuses on the positive and negative attributes associated with various indicators to further assess the high-quality development level of green marketing within China's manufacturing sector. The specific standardization formula is presented below. Data standardization is conducted based on the directional influence of GDP rankings for indicators where determining positive or negative attributes proves challenging. Weights are assigned using the entropy value method, and their cumulative total results in the final index for high-quality development in green marketing. The formula is as follows:

$$\text{Positive standardization: } z_{\theta ij} = \frac{\max x_j - x_{\theta ij}}{\max x_j - \min x_j} \qquad (1)$$

$$\text{Negative standardization: } z_{\theta ij} = \frac{\max x_j - x_{\theta ij}}{\max x_j - \min x_j} \qquad (2)$$

Where $z_{\theta ij}$ stands for the standardized value corresponding to the j_{th} indicator for the i_{th} province in the year the θ_{th} year, $x_{\theta ij}$ the value of the specific indicator corresponding to the j_{th} indicator in the i_{th} province in the θ_{th} year, $\max_{xj}$, $\min_{xj}$ represent the maximum and minimum observed values of the j_{th} indicator in the θ_{th} year for the i_{th} province, respectively. After that, the weight $P_{Oij} = z_{oij} \left(\sum_{i=1}^{n} z_{oij} \right)^{-1}$ occupied by the j_{th} indicator in

the ith province is calculated, and the entropy value $e_{oij} = \left(\sum_{i=1}^{n} P_{oij} \log P_{oij} \right) \cdot \left(\ln(n) \right)^{-1}$ of the j_{th} indicator is calculated, where n stands for the number of sample sizes under the ln(n) table for a given year. Calculate the coefficient of variation of the j_{th} indicator $g_{oj} = 1 - e_{oj}$ and the corresponding weight is

$w_{oj} = g_{oj} \left(\sum_{i=1}^{n} g_{oj} \right)^{-1}$. The final indicator of green and high-quality marketing development of the manufacturing industry: $S_{oi} = \sum_{i=1}^{n} w_j \cdot P_{ij}$.

Core Explanatory Variables: The measurement of the digital economy's development level is still in its nascent stages, and scholars have yet to establish a unified standard. Xu and Zhang (2020) argue that the digital economy primarily comprises four key components: digital empowerment infrastructure (Led Enabling Infrastructure), digital media (Led Media), digital transactions (e-commerce), and digital economy trading products (Led Economy Trading Products). Zhao et al. (2020) developed a comprehensive index for assessing digital economy development, focusing on two primary dimensions: internet advancement and digital financial inclusion. Building upon existing literature, this article integrates the connotation and extension of the digital economy to establish an index system that evaluates the level of digital economic development from a macro perspective. This system encompasses three key aspects: digital infrastructure, the evolution of digital transactions, and innovations in digital applications and their outputs, collectively serving as indicators for measuring progress in digital economic development.

Data are first standardized using the maximum-minimum value method to compare the level of digital economic development with green marketing in China's regional manufacturing industry. Subsequently, the entropy value method is employed for assignment, leading to the final determination of the digital economic development index. The level of development of the digital economy is represented as (Led). Definitions and measurements for specific sub-indicators are presented in Table 3.

Table 3. Digital economy development index

First-level indicators	Secondary indicators	Variables	Unit	Targets
Digital Infrastructure	Internet penetration	Number of Internet broadband access ports	ten thousand	Positive
		Number of Internet broadband access users	ten thousand households	Positive
		Number of Internet domain names	million	Positive
	Cell phone penetration	Cell phone base station density	units/ square kilometer	Positive
		Mobile phone penetration rate	Department/ Hundred	Positive
	Breadth of information transmission	Length of long-distance fiber optic cable per unit area	Kilometer/ square kilometer	Positive
Digital transaction development	Basis of digital transactions	Number of computers used by enterprises per 100 people	people	Positive
		Number of websites per 100 enterprises	Number	Positive
		E-commerce enterprises	% of	Positive
	Impact of digital transactions	E-commerce sales	Billions of dollars	Positive
		Online retail sales	billion	Positive
Digital innovation inputs and outputs	Innovation Inputs	R&D Expenditure of Industrial enterprises above scale	million	Positive
		Number of R&D projects (topics) of industrial enterprises above large scale	Item	Positive
		R&D investment in high-tech industries as a proportion of total R&D Investment number of patent applications and authorizations (pieces)	million	Positive
	Innovation Outputs	Sales revenue of new products	million	Positive
		Technology market turnover	million	Positive

Mediating Variables: This paper identifies market integration (Segm), industrial structure upgrading (Istr), and the level of marketization (market) as mediating variables. The statistics concerning various commodities and factor price indices are already highly detailed, with these indices effectively reflecting a market economy's dynamics. Therefore, employing the "glacier cost" model as a foundation, this article utilizes the relative price method to assess both inter-regional market integration and the level of marketization in China. Additionally, it measures industrial structure upgrading through the ratio of value added from the tertiary industry to that from the secondary industry.

The following variables were controlled to ensure the consistency of findings: first, environmental regulation (Even), defined as the ratio of investment in pollution control to Gross National Product (GNP); second, environmental pollution control investment (Inven), measured by the ratio of the combined operating costs for industrial wastewater treatment and exhaust gas management to the total value of industrial output; third, the level of economic development (Eco) is represented by selected gross regional figures. Fourth, the level of government expenditure (Gov), which reflects the strength of governmental support, is measured using the proportion of government funds allocated to R&D in industrial enterprises above a designated size. Fifth, foreign direct investment share (Fdi) is indicated as the logarithm of total foreign direct investment. Sixth, GDP per capita is expressed as the ratio of regional GDP to the total population within that region

2.3.2. Construction of the spatial Durbin model

In this article, the adjacency weight matrix is used, and the expression is:

$$W = \begin{cases} 1, & \text{Province } i \text{ and province } j \text{ are contiguous} \\ 0, & \text{Province } i \text{ and province } i \text{ are not contiguous} \end{cases} \tag{3}$$

Spatial Measurement Model

To more effectively assess the impact and spatial spillover effects of the digital economy on the high-quality development of green marketing within China's manufacturing sector, we propose the following spatial Durbin model:

$$Ghmmi_{it} = \alpha + \rho W Ghmmi_{it} + \delta_1 Led_{it} + \beta_1 WLed_{it} + \delta_2 X_{it} + \beta_2 WX_{it} + \mu_i + \eta_t + \varepsilon_{it} \tag{4}$$

Multivariate model:

$$Segm_{it} = \alpha + \rho W Ghmmi_{it} + \delta_1 Led_{it} + \beta_1 WLed_{it} + \delta_2 X_{it} + \beta_2 WX_{it} + \mu_i + \eta_t + \varepsilon_{it} \tag{5}$$

$$Istr_{it} = \alpha + \rho W Ghmmi_{it} + \delta_1 Led_{it} + \beta_1 WLed_{it} + \delta_2 X_{it} + \beta_2 WX_{it} + \mu_i + \eta_t + \varepsilon_{it} \tag{6}$$

$$Maket_{it} = \alpha + \rho W Ghmmi_{it} + \delta_1 Led_{it} + \beta_1 WLed_{it} + \delta_2 X_{it} + \beta_2 WX_{it} + \mu_i + \eta_t + \varepsilon_{it} \tag{7}$$

Where $Ghmmi_{it}$ refers to the green marketing and high-quality development index for China's manufacturing industry, Led_{it} denotes the digital economy development level index, X_{it} is a control variable, α is a constant term, μ_i and η_t denote the individual and time effects, respectively, and ε_{it} is a random perturbation term. When the coefficient $\beta_i (i = 1, 2)$ in the SDM model is 0, the spatial interaction does not exist, and the model degenerates to the SAR model; when the coefficient in the SDM model satisfies $\beta_i = -\delta_i \times \rho (i = 1, 2)$, the model degenerates to the SEM model. In the article, the optimal spatial model suitable for the article will be determined by correlating the model with the LM test, LR test, and Hausman test. Regarding the spatial weight matrix, considering that the digital economy has transcended the limitation of geographic location, the article constructs the economic distance weight matrix based on the mean value of per capita GDP of all years in the sample period of each province. Meanwhile, to better validate the measurement of the impact of the digital economy on the high-quality development of green marketing in China's manufacturing industry, this article selects market integration (Segm), industrial structure upgrading (Istr), and the level of market development (Market) as the mediator variables to construct the mediation model, and by analyzing the mediator variables, the article further verifies whether the effect of the explanatory variables on the core variables is realized through the mediator variables.

2.4. Verification mode

2.4.1. Moran's I test

Before conducting the empirical analysis of the spatial Durbin model, it is essential to perform a spatial autocorrelation test on the explanatory variable representing the level of development of the digital economy (Led) and the explanatory variable pertaining to green marketing high-quality development within China's manufacturing industry (Ghmmi). This step aims to determine whether a spatial correlation exists in the data,

thereby informing our decision on the appropriateness of proceeding with spatial Durbin analysis. The specific results of this test are presented in Table 4.

Table 4. Manufacturing industry green marketing high-quality development and digital economy full development level global Moran's I index

Particular year	Ghmmi			Led		
	Moran's I	Z	P-value	Moran's I	Z	P-value
2013	0.4646	3.0758	0.0023	0.2445	2.1165	0.0413
2014	0.4768	3.1289	0.0016	0.2349	1.7262	0.0932
2015	0.4427	2.9440	0.0039	0.2380	1.7499	0.0880
2016	0.4789	3.1960	0.0013	0.2939	1.6946	0.0779
2017	0.3866	2.5989	0.0096	0.2939	1.6747	0.0876
2018	0.4048	2.7259	0.0069	0.2967	1.9116	0.0458
2019	0.3628	2.4839	0.0138	0.2305	1.7834	0.0840
2020	0.3639	2.4904	0.0127	0.2276	1.7327	0.0867
2021	0.3289	2.2658	0.0238	0.2403	1.8209	0.0839
2022	0.4056	2.7019	0.0068	0.2524	2.1049	0.0936
Overall inspection	0.0910	2.2477	0.0130	0.3000	7.8930	0.0000

For the Moran's I test, the specific formula is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}\left(x_i - \overline{x}\right)\left(x_j - \overline{x}\right)}{s^2 \sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}} \tag{8}$$

From the formula above, it is evident that when Moran's I exceeds 0, this indicates a positive spatial correlation within each region; furthermore, the closer its value approaches 1, the stronger the positive correlation. Conversely, as it nears -1, the intensity of negative spatial correlation increases. Based on the aforementioned data, it is evident that the overall Moran's I for the high-quality development of green marketing within China's manufacturing sector and the advancement of the digital economy is positive. This finding passes the 5% significance test, indicating a substantial positive spatial correlation between the level of high-quality development in green marketing and the degree of digital economic development in China's manufacturing industry. Annual data on the level of high-quality development in green marketing within China's manufacturing sector exhibits considerable fluctuation, likely attributable to the intervals between measurements. In contrast, Moran's I index for the digital economy has consistently remained positive over recent years, with all values achieving significance at the 5%. Overall, this trend appears relatively stable.

2.4.2. Spatial autocorrelation model selection test

Commonly employed tests for the selection of spatial autocorrelation models include the LM, LR, and Wald tests. The results of these tests are presented in Table 5. As indicated in Table 5, the LM test statistics all exceed the 5% significance level, affirming the appropriateness of selecting the spatial measurement model.

Table 5. Spatial measurement model selection test results

Testing for Panel Spatial Models		Value	P-Value
LM test	Moran's I	7.345***	0.0000
	LM-lag	49.101***	0.0010
	Robust-LM-lag	69.919***	0.0000
	LM-error	6.267**	0.0120
	Robust- LM-error	27.48***	0.0000
LR test	LR-SDM-SEM	19.17***	0.0081
	LR-SDM-SAR	19.10***	0.0068
Hausman		16.625	0.0140

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

According to the test results presented in Table 5, it is evident that the p-value of the LM test is significantly less than 0.05, indicating that all p-values are significant. This supports the acceptance of the null hypothesis, which asserts no autocorrelation among the variables. Based on these findings, appropriate model selections include the Spatial Autoregressive (SAR) model, Spatial Error Model (SEM), or Spatial Durbin Model (SDM). The results from the LR test indicate that the SDM model can be reduced to either a SAR or SEM model. Furthermore, both models demonstrate significance at a level of 0.5%, confirming effective parameter constraints and non-degeneracy. In light of the Hausman test results – wherein a probability value falls within $0 < P < 0.05$ – we reject the null hypothesis, suggesting that a fixed effect model outperforms a random effect model for this analysis. Consequently, we advocate for selecting the Spatial Durbin Fixed Effect Model for further testing. Integrating insights from these three testing methodologies indicates that opting for a fixed effect model proves more advantageous than employing a random effect model during empirical analysis; thus, we recommend choosing a fixed effect approach.

3. Results and Discussion

3.1. Spatial test results

The analysis employs the digital economy and the high-quality development of green marketing within China's manufacturing industry as key variables. We present the following regression table through a spatial regression test that integrates double fixed effects regression analysis and spatial Durbin regression analysis. From this, we can draw several conclusions: First, the results from all three analyses indicate that the core explanatory variables achieve significance at a 10% level. Adding control variables significantly enhances the significance of the double fixed effects model, suggesting a more robust analytical framework. Furthermore, in light of this increased robustness and the findings from the SDM regression analysis, it is evident that the digital economy exerts a significant negative impact on China's manufacturing sector, green marketing initiatives, and high-quality development (significance level: 10%).

Table 6. Table of benchmark regression results of digital economy and high-quality development of green marketing in China's manufacturing industry

Variant	OLS		FE fixed effects		SDM
	(1)	(2)	(3)	(4)	(5)
Led	3.219*** (0.19)	1.511*** (0.22)	0.731*** (0.24)	0.612* (0.29)	0.799** (0.31)
Even		-1.320*** (0.18)		-0.227 (0.26)	-0.231 (0.39)
Inven		-0.095*** (0.02)		0.029 (0.02)	0.037* (0.02)
Eco		1.242*** (0.18)		0.772** (0.33)	0.415 (0.42)
Gov		-0.003 (0.01)		0.029*** (0.01)	0.035** (0.01)
Fdi		0.549** (0.22)		-0.958*** (0.30)	-1.299*** (0.30)
Gdp		-0.007 (0.05)		-0.0456 (0.05)	0.001 (0.04)
W×Led					3.98*9 (1.95)
rho					-0.991*** (0.15)
Year	No	No	Yes	Yes	Yes
Province	No	No	Yes	Yes	Yes
N	3000	3000	3000	3000	3000
R^2	0.507	0.545	0.576	0.599	0.671

At the same time, the significantly positive rho value of 1% indicates a notable spatial spillover effect for the high-quality development of green marketing in China's manufacturing industry. Specifically, an increase in one region positively influences the development of neighboring regions. Third, the spatial weight interaction term W×Led coefficient of the spatial Durbin model is significantly positive, i.e., advancements in the digital economy within adjacent regions facilitate high-quality development on high-quality development of green marketing in China's manufacturing industry. This regression analysis further substantiates Hypothesis 1. On the one hand, the advancement of the digital economy fosters technological progress in digital technologies within the region, facilitates the free movement of marketing factors across regions, and enhances the high-quality development of green marketing in other areas through digital spillover effects. On the other hand, the digital economy dismantles spatial and temporal constraints, expands market scale, and strengthens communication and collaboration concerning inter-regional green marketing within the manufacturing sector, promoting overall high-quality development in green marketing.

3.2. Discussion on the decomposition of spatial effects

It is essential to differentiate the spatial effects of the digital economy from those of the control variables to conduct a more comprehensive analysis of the impact of high-quality development in green marketing within China's manufacturing sector.

Table 7. Results of decomposition of spatial effects

Variable	Direct effect	Indirect effect	Total effect
Led	0.768* (0.41)	1.834* (0.76)	2.584** (1.00)
Even	-0.163 (0.31)	-1.214 (1.27)	-1.328 (1.21)
Inven	0.029 (0.02)	0.168* (0.08)	0.140*** (0.08)
Eco	0.262 (0.41)	2.749** (1.30)	3.030** (1.33)
Gov	0.033*** (0.01)	-0.015 (0.05)	0.013 (0.06)
Fdi	-1.049*** (0.26)	-3.029* (1.84)	-4.123** (1.83)
Gdp	-0.024 (0.04)	0.333* (0.20)	0.358 (0.20)

The analysis presented in Table 7 indicates that the direct effect coefficient of the digital economy on enhancing the high-quality development of green marketing within China's manufacturing sector is 0.768, which is statistically significant at the 10% level. Additionally, the indirect effect coefficient stands at 1.834, which is also significant at the 10% level, while the total effect coefficient reaches 2.584, which is significant at the 5% level. The impact coefficient derived from employing a spatial model suggests that the influence of the digital economy on high-quality green marketing development in China's manufacturing industry is greater than previously estimated. This finding underscores that advancements in the digital economy within neighboring regions substantially contribute to fostering high-quality growth in green marketing across this sector in China.

3.3. Discussion of the robustness test of the digital economy to the high-quality development of green marketing in China's manufacturing industry

It is essential to assess the robustness of both the equation and its variables to enhance the explanatory power of the test indicators and the validity of the test results. Among various methods for conducting robustness tests, this paper employs both the alternative variable method and the fixed effects control method. The empirical test model's and its variables' robustness is evaluated by substituting industrial sales profit for high-quality development in green marketing within China's manufacturing sector. The findings are presented in column 1 of Table 8. As calculated by the Fifth Institute of Electronics under the Ministry of Industry and Information Technology, the digital economy development index supersedes the digital economy development index presented in this paper. The corresponding test results are displayed in column 2 of Table 8. The robustness test results for the two methods are presented in Table 8. Additionally, this study employs a fixed effects

control method to conduct a stability test, primarily focusing on controlling the fixed effects of provinces and regions as well as the interaction effects between provinces and years. The specific test outcomes are displayed in columns 3 and 4 of Table 8.

Table 8. Robustness test results

Variable	Substitution of variables method		Controlled fixed effects approach	
	Replacement of the dependent variable	Replacing the independent variable	Controlling for province effects	Controlling for year effects
Led	-0.316* (-1.899)	-0.315** (-2.16)	-0.346*** (-3.29)	-0.329*** (-3.19)
Control variable	Yes	Yes	Yes	Yes
Province effect	No	No	Yes	Yes
Year effect	No	No	No	Yes
Time fixed	Yes	Yes	Yes	Yes
R^2	0.42	0.47	0.50	0.51

From the analysis above, it is evident that substituting industrial sales profit with the high-quality development of green marketing in China's manufacturing sector yields a negative result at the 10% significance level. Additionally, when replacing the digital economy development level with the digital economy index, a negative outcome is observed at the 5% significance level. This suggests that China's digital economy exerts an inhibitory effect on the high-quality development of green marketing within its manufacturing industry, indicating robust test results. Similarly, findings from applying fixed-effects control methods also demonstrate significant robustness.

3.4. Test of spatial heterogeneity results

Due to the phenomenon of resource endowment and variations in economic development levels across different regions, this paper utilizes the classification of 30 provinces into eastern, central, western, and northeastern economic regions as published on the official website of the National Bureau of Statistics. Building upon this framework, we investigate the heterogeneity in the impact of the digital economy on high-quality green marketing development within China's manufacturing sector across these distinct economic regions. The table below indicates that, when analyzed in conjunction with the regression coefficients of the standardized data, the digital economy exerts the most significant influence on the high-quality development of green marketing within China's manufacturing sector, particularly in the eastern region. Its impact follows this in the northeastern, central, and western regions.

Table 9. Results of the heterogeneity test by sub-economic region

Variables	Eastern Region	Central Region	Western Region	Northeast Region
Led	0.168** (0.067)	0.040*** (0.019)	-0.057** (0.021)	0.140* (0.059)
W×Led	0.017 (0.070)	-0.057 (0.095)	0.069* (0.040)	-0.183*** (0.031)
Rho	-0.345*** (0.078)	0.457*** (0.109)	0.410*** (0.059)	0.510*** (0.074)
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
N	3000	3000	3000	3000
R^2	0.415	0.457	0.502	0.544

The primary reason for this phenomenon may be attributed to the relatively advanced economic development in the eastern region over recent decades, particularly compared to the western and northeastern regions. The robust growth of the digital economy in this area has also contributed to a higher quality of green marketing development. Moreover, considering the corresponding rho value, it is evident that the spatial autocorrelation

coefficient for the eastern region exhibits a significantly negative correlation at the 1% significance level. This finding suggests that the high-quality development of green marketing within China's manufacturing sector has resulted in a pronounced siphoning effect in the eastern region. The spatial autocorrelation coefficient in the western and northeastern regions is significantly positive at a 1% significance level, indicating a favorable spatial spillover effect for the high-quality development of green marketing within China's manufacturing sector. This suggests that advancements in one region can effectively stimulate progress in other regions. Conversely, it is noted that the spatial interaction term in the eastern region lacks statistical significance, which may imply the presence of a potential spatial threshold effect. In contrast, the coefficient for the spatial interaction term in the western region is significantly positive at the 10% level. This indicates that the advancement of the digital economy in adjacent regions significantly enhances the high-quality development of green marketing within China's manufacturing sector, particularly in cities in the western region.

3.5. Mediating role of market integration and upgrades to the industrial structure

The results in column (1) of Table 10 indicate that the coefficient for the interaction term Led×Istr, which represents the interplay between the digital economy and upgrades to the industrial structure, is significantly positive at the 1% level. This finding suggests that such upgrades substantially enhance the impact of the digital economy on high-quality development in green marketing within this region. Furthermore, the spatial interaction term W×Led×Istr coefficient is significantly negative, indicating that industrial structure upgrades occurring in other regions do not produce digital spillover effects on this particular region. This outcome supports Hypothesis 2. The current state of upgrades to the industrial structure remains inadequate. The indiscriminate implementation of restrictions and protections hinders the synergistic advancement of high-quality green marketing development. Economic growth driven by scientific and technological progress and enhancements to the industrial structure are crucial for fostering high-quality development in green marketing and achieving a mutually beneficial outcome. From the results presented in column (2) of Table 10, it is evident that the interaction term Led×Segm, which represents the relationship between the digital economy and market integration, is not statistically significant. In contrast, the coefficient for the spatial interaction term W×Led×Segm exhibits a significantly positive value. This finding indicates that the moderating effect of market integration is more pronounced across regions.

Table 10. Moderating effects of IPR protection and market integration

Variables	Upgrading of industrial structure(1)	Market integration(2)	Level of marketization(3)
Led	0.129 (0.60)	0.786** (0.29)	-1.408 (1.19)
Istr	-0.182* (0.13)		
Led×Istr	0.219* (0.13)		
Segm		1.168 (2.23)	
Led×Segm		-2.356 (3.29)	
Market			-0.101 (0.08)
Led×Market			0.189* (0.15)
W×Led	10.368** (4.78)	2.478 (2.79)	5.085* (2.58)
W×Istr	1.401 (0.97)		
W×Led×Istr	-1.678* (1.06)		
W×Segm		-33.789* (17.45)	
W×Led×Segm		55.300* (28.76)	
W×Market			0.234** (0.12)
W×Led×Market			0.243* (0.18)
rho	-0.897*** (0.18)	-1.760*** (0.21)	-0.768* (0.07)
Year	Yes	Yes	Yes
Province	Yes	Yes	Yes
N	3000	3000	3000
R^2	0.39	0.42	0.44

4. Conclusion and Recommendations

This paper analyzes statistical data from 30 provinces, autonomous regions, and municipalities directly under the central government of China for the period from 2013 to 2022 to examine the impact of the digital economy on the high-quality development of green marketing within China's manufacturing sector, as well as its spatial spillover effects. Through a comprehensive literature review, theoretical analyses, and empirical design, we empirically assess how the digital economy's advancement influences high-quality green marketing development in China's manufacturing industry and its associated spatial spillover effects. The study reveals that (1) the digital economy has significantly facilitated the high-quality development of green marketing throughout the research period, and this conclusion is robust. (2) The digital economy promotes the high-quality advancement of green marketing through two primary mechanisms: enhancements in industrial structure and market integration. (3) There is no threshold effect regarding upgrades to the industrial structure on the influence of the digital economy on the high-quality development of green marketing within the manufacturing sector. Conversely, a threshold effect does exist for market integration concerning this same impact. As market integration continues to improve, this threshold effect exhibits a marginally increasing trend. (4) The influence of the digital economy on the high-quality development of green marketing exhibits heterogeneity across different regions and varying policy intensities. This promotional effect is notably significant in the eastern region but not evident in the central or western regions. Based on these findings, this paper proposes the following policy recommendations, taking into account both the empirical results and the current state of urban development in China.

The in-depth integration of the digital economy and the manufacturing industry should be deepened, and a better system for developing the digital economy should be built. The digital economy should be vigorously developed. A new generation of digital infrastructure, including cloud computing, the Internet of Things, and data centers, should be established. Applying emerging technologies such as robotics, big data, and 5G should be accelerated. It is essential to fully leverage the significant role of the digital economy in transforming and upgrading industrial structures. Emphasis should be placed on fostering industries and high-tech enterprises centered around the digital economy. The acceleration of digital technology application in high-quality green marketing within the manufacturing sector is essential, accompanied by institutional innovation. A robust implementation of a digitalization strategy should be pursued alongside formulating laws and regulations pertinent to the digital economy. Policies and measures not aligned with the evolving landscape of the digital economy and green marketing need to be adjusted promptly. Furthermore, significant challenges encountered in achieving high-quality development within both the digital economy and green marketing must be thoroughly examined and addressed expeditiously. A series of preferential policies have been implemented to encourage traditional manufacturing industries to actively integrate into the digital economy, the platform economy, the sharing economy, and other new business forms and modes and to promote intelligent production, diversified operations, sales platforms, and refined management in the manufacturing industry, so as to realize the transformation of China's manufacturing power into a manufacturing power.

A differentiated development strategy should be implemented to foster the synergistic and inter-connected growth of the manufacturing industry across regions. The eastern region is encouraged to advance the digital industry's rapid expansion actively, enhance network platform supply capacity, and improve the service capabilities related to digital information. Furthermore, it is essential to promote integrating the digital economy with high-quality green marketing development. Both high-tech and traditional technology manufacturing industries should be incentivized to adopt an "online + offline" marketing model to promote and sell consumers green products. Additionally, there is a significant opportunity to fully leverage data as a vital factor of production. Provincial governments in the central and western regions should enhance financial support; improve infrastructure, including fiber optic cables, broadband access ports, and mobile phone base stations; strengthen the cultivation and introduction of high-quality talent; and establish a fair and orderly market environment. These measures are essential to provide robust environmental support for integrating the digital economy with the high-quality development of green marketing within the manufacturing sector.

The government should be acutely aware of the constraints imposed by the external environment on the role of the digital economy in fostering high-quality development of green marketing within China's manufacturing sector. It is imperative that the environmental regulation mechanism undergo continuous enhancement alongside a strengthening of enforcement measures. Manufacturing enterprises engaged in digital economy marketing must adhere rigorously to relevant environmental regulations, ensuring that production and sales practices align with established environmental standards and requirements. In the context of the technological environment, a scientific and rational allocation of capital, optimal distribution of innovation inputs and digital economy resources, enhancement of energy efficiency, and reduction in waste emissions can collectively foster the green upgrading of industries. This transformation can potentially create new green and high-quality

markets for manufacturing enterprises. In the context of the trade environment, it is crucial to capitalize on the opportunities presented by the Belt and Road Initiative to enhance the regional investment climate and facilitate the introduction of advanced technologies and expertise. Concurrently, it is essential to raise entry barriers appropriately to mitigate the crowding-out effects posed by low-quality and high-pollution enterprises on domestic manufacturing industries.

In the digital era, green development requires the advancement and support of digital technology and the digital economy, effective social co-governance, and active public participation. The role of the digital economy in fostering high-quality development in green marketing within China's manufacturing sector should be continuously enhanced through three key dimensions: government, enterprises, and citizens. The government should enhance digital environmental regulation and supervision while formulating more scientific and effective environmental policies and regulations. Manufacturing companies ought to leverage digital technology to develop and promote environmentally friendly products and services and advocate for green marketing principles. The public can engage in green purchasing and sustainable consumption activities through the Internet and social media platforms, thereby playing a significant role in environmental governance.

Although this study elucidates the mechanisms through which the digital economy influences the high-quality development of green marketing in China's manufacturing sector, there remains significant potential for further enhancement. First and foremost, due to data availability constraints, this paper focuses exclusively on impacts at the provincial level; future research could benefit from a more granular analysis from the prefecture-level city perspective. Secondly, while applying the spatial Durbin model presupposes certain spatial dependencies among regions, real-world scenarios may exhibit greater complexity. The current model does not fully account for other possible nonlinear relationships and dynamic effects. Future investigations should consider refining model specifications by incorporating nonlinear models or dynamic panel data approaches to capture intricate economic interactions more accurately.

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