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Digital Transformation and Carbon Intensity: Evidence from Chinese Tourism Companies

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Abstract: The flourishing of the tourism market generates gigantic carbon emissions. It is imperative for tourism companies to take action to achieve decarbonization. The emergence of digital technology is gradually becoming an important strategic path for global corporations' technological evolution. Undoubtedly, digital tools provide a fresh opportunity for tourism companies to reduce their carbon footprint. Realizing the positive interaction between digitization and greenization is essential for tourism companies to achieve high-quality development. Aiming to clarify the relationship between digital transformation and company carbon intensity in tourism companies, this study analyzes the influence and mechanism of digital transformation on tourism companies' carbon intensity using data from Chinese A-share listed tourism companies over the period 2005–2020. With the help of textual analysis and high-dimensional fixed effects model, this paper builds a proxy for digital transformation and further tests the causal link between digital transformation and company carbon intensity. The findings indicate that digital transformation significantly reduces the carbon intensity of tourism companies. Alleviating managerial myopia, attracting external resources, and fostering a collaborative culture are three mechanisms through which digital transformation can exert its carbon reduction efficacy. The heterogeneity analysis reveals that this effect is more prominent among state-owned tourism companies, companies with greater board diversity, or companies situated in more favorable business environments. This paper makes three contributions. First, this paper broadens the exploration of how digital advancements affect tourism, discussing the relationship between digital transformation and the carbon intensity of tourism companies. Second, this paper looks beyond a macro perspective commonly used in tourism carbon emission research, undertaking the research at the micro level, filling the research gap in tourism companies' carbon performance. Third, from the aspect of informational effect, this paper provides the mechanism between digital transformation and tourism company carbon intensity creatively. The conclusions offer empirical insights to assist tourism companies in effectively fulfilling their environmental commitments in the digital era. Meanwhile, this paper also provides a useful decision-making basis for the government to promote tourism companies' decarbonization transformation. From the company perspective, tourism companies should take digitalization seriously, fully exploiting the environmental benefits of digital transformation. From the government perspective, local government should further improve the environment for company development, supporting tourism companies' digital transformation with unremitting efforts.

Keywords: digital transformation; company carbon intensity; managerial myopia; resource attraction; collaborative culture

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1. Introduction

Climate change is one of the greatest threats to humanity by far. In response to this global challenge, some 150 nations and regions have put forth carbon neutrality strategies. Sustainable development has been elevated to an unprecedented strategic level, which has become an international consensus. The net-zero emission target is a broad and profound systemic change. Confronting this complex challenge requires concerted efforts from the whole of society. It can be argued that any lack of environmental and social responsibility could negatively impact the steady land of carbon reduction strategies. As a vital part of the modern service sector, actively answering calls for dual carbon goals is crucial for the tourism industry to achieve sustained, healthy development. Contrary to popular belief of a "smoke-free industry", the carbon emissions caused by tourism are alarming, accounting for 8% of the world total [1]. There is every indication that tourism is actually a carbon-intensive economic sector [2]. On the supply side, the large amounts of energy consumed by hotels and resorts for air conditioning, heating, lighting, and other amenities make reducing carbon emissions difficult. On the demand side, travelers' anticipation of novelty experiences has been fueled by the rise of income, which has pushed them further afield via cars, cruise ships, aircraft, and other energy-intensive ways [2]. Tourism companies are the micro-entities of the tourism market, which is an important emitter of greenhouse gases. In 2021, the World Tourism Organization launched "Climate Action in the Tourism Sector". More than 300 tourism companies and relevant governments have co-signed a declaration committing to achieve industry-wide net zero by 2050 at the latest. However, recent research suggests that large tourism companies are still not on the track of decarbonization. The realistic requirement to cut carbon emissions prompts large tourism companies to consider how to undertake more sweeping operational changes in order to fulfill their pledge made under the carbon neutrality goal [3].

The swift advancement of digital technology has made digital transformation an essential trend for companies looking for superior development. Especially under the dual pressures of economic downside and rising uncertainty, more and more tourism companies have treated digital transformation as their primary strategy with a view to finding a way to break the deadlock in the face of adversity. In recent years, digital technology has fully penetrated into all scenes of tourism activities. The introduction of emerging technologies such as online booking, virtual tours, and guest monitoring creates key entry points for tourism companies to break down industry barriers, break through the traditional mode of operation, and drive the flow of factors across space and time, representing the future direction of the tourism industry. Digitalization is more than just a technical revolution; particularly under the "dual-carbon" framework, the ecological effect of digitalization has steadily gained attention in theory and practice.

The tourism experience plays an essential role in shaping tourist behavior and raising their ecological awareness. Through close contact with nature, the slowly dawning realization that environmental degradation and animal extinction would have devastating consequences for humanity. These experiences provoke emotional responses, which often lead to more environmentally responsible behavior both during and after their travels [4]. For example, after a marine tour, tourists, out of concern and compassion for marine life, may be more inclined to reduce plastic use and choose clean energy, thereby providing ongoing support for ecological causes.

As an important strategic change [5], digitization surely opens up new possibilities for the low-carbon transformation of tourist companies. So, what kind of environmental consequences does digital transformation have within tourism companies, and can it become a new kinetic energy driving these companies to reduce carbon emissions? What type of transmission mechanism exists between the two? Exploring these issues will provide new ideas for tourist companies to address the carbon reduction challenge, which is critical for shoring up the low-carbon economy under the current circumstances.

As the biggest developing country in the world, China's tourism market is enormous. So far, China has become the biggest domestic tourism market, the largest source of international tourists, and a main destination for international travelers. Frequent tourism activities make China the second largest tourism carbon emitter in the world [2]. Thus, the study of Chinese tourism companies' carbon emissions is necessary. This paper takes Chinese tourism companies as the research object with a view to providing empirical evidence for other developing countries and even the whole international community of a feasible development path toward tourism's decarbonization.

To clarify the complex relationship between digital transformation and company carbon intensity, identify the environmental benefit of digital transformation in tourism companies, and establish the mechanism of digital transformation on tourism company carbon intensity, this paper takes Chinese A-share listed tourism companies from 2005 to 2020 as samples and investigates whether digital transformation can release its dividend of carbon reduction in tourism companies.

When compared to previous studies, the paper's contributions are most apparent in the following areas: (1) Research content. This paper broadens the exploration of how digital advancements affect tourism beyond just their economic impacts. Previous literature mostly focuses on the financial consequences of tourism companies' digital transformation [6,7], often ignoring its impact on environmental performance. This paper can be a useful complement to this gap by systematically examining the causal association between digital transformation and carbon intensity in tourism companies. (2) Research perspective. This paper looks beyond a macro perspective commonly used in tourism carbon emission research, undertaking the research at the micro level. It also emphasizes the significance of digital applications in the process of low-carbon transformation, providing a scientific basis for tourism companies to drive greenization by digitization in the context of carbon peaking and carbon neutrality. (3) Unlike the typical "scale-structure-technology" analytical framework, this paper attempts to explain the process of releasing digital transformation's green benefits through the lens of the informational effect. Focusing on the role of digital transformation in reducing information asymmetry, this paper presents mechanisms from three perspectives: alleviating managerial myopia, attracting external resources, and fostering a collaborative culture. This further deepens the understanding of the causal link between digital transformation and tourism company carbon intensity.

In this paper, it is found that, against the background of dual carbon goals, tourism companies should embrace digital technologies to improve their environmental performance. They should further enhance their internal and external information environments by digitizing and assembling a diverse board of directors, eventually improving their environmental performance. Local government should attach great importance to tourism companies' actual needs and work hard to improve the business environment, which will provide a solid base for tourism companies' digital transformation.

2. Literature Review and Theoretical Hypotheses

2.1. Literature Review

2.1.1. Consequences of Digital Transformation

Accompanied by the exponential growth of the new generation of digital technology, concepts related to digitization have gradually come into the spotlight. Digital transformation is a strategic choice of companies in the wave of the coming age, emphasizing a practical use of digital technology, that is, utilizing digital instruments to achieve a complete reengineering of the production operations, business processes, and business models [8]. A plethora of studies have already explored the economic impacts of digital transformation, confirming the positive role of digital transformation in improving companies' human capital, financial performance, market value, and productivity [9–11]. Some other researchers also found that digital transformation enhances corporate governance environments. Specifically, digitalization improves companies' data analytics capabilities, contributing to overcoming the problem of information asymmetry by increasing the availability of information and data [12,13]. A more transparent information environment develops managers' decision-making capacity, which in turn improves the operational management of companies. In terms of the environmental impacts of digital transformation, thus far, there has been no academic consensus on this issue. In theory, digital transformation does not necessarily lead to lower carbon emissions. On the one hand, there is much evidence that digital transformation can exploit a positive impact on companies' carbon emissions reduction through multiple paths, such as improving energy efficiency, lowering renewable energy costs, and encouraging technological innovation [14,15]. On the other hand, digital technology is energy-intensive in itself [16], which may lead to an increasing risk of environmental degradation. For example, in China, the electricity consumption of data centers was 160.9 billion kWh in 2018, accounting for 2.35% of the national total. In addition, the ramped-up production from digitization can also trigger a series of rebound effects, resulting in a more rapid rise in carbon emissions [17]. In conclusion, it is still unclear whether digital transformation creates a carbon-reduction effect. This might be due to the impact of digital transformation on carbon emissions highly depending on the company's characteristics. Most existing research has concentrated on industrial or manufacturing firms, while service companies, including tourism, have often been excluded from the analysis. Specific research for tourism companies may provide new insights and different conclusions.

2.1.2. Digital Transformation in Tourism

The integration of digital and tourism has become a new normal. The application of 5G networks and Big Data technology shrinks the space between tourists and tourism suppliers [18], allowing suppliers to gather and analyze customer data, including travel preferences, previous travel history, and behavior patterns. This enables the provision of customizable travel packages that align with individual needs, resulting in more meaningful and satisfying tourism experiences [11,19]. Emerging technologies in tourism are not only a convenience for tourists but also a way to reduce costs for tourism companies. Companies can greatly enhance their marketing and distribution capabilities through e-commerce services. Digital marketing platforms provide low-cost channels for advertising, which reduces the need for expensive traditional marketing campaigns [20]. No longer relying on offline offices, tourism companies can directly reach tourists through targeted digital ads or personalized email, significantly lowering transaction costs [21]. Furthermore, digitalization facilitates transparency in the tourism marketplace, leading to a reshuffling of the competitive landscape [22]. Benefiting from the unrestricted information flow, tourists receive access to a wealth of knowledge about destinations, market conditions, and the background of service providers. It's much easier than before for them to make informed decisions by browsing online reviews. This trend objectively raises higher requirements for all tourism companies, virtually applying the pressure of responsible environmental behaviors. As the concept of sustainable development gains traction, travelers are becoming increasingly environmentally conscious. A survey conducted by Booking.com reveals that nearly 90% of the respondents expressed their intention to travel in a low-carbon way. In response to such a change, tourism companies should take a host of actions to conform to the digital tide. Try to gain consumers' favor by promoting sustainable practices to build a responsible and trustworthy corporate image on the Internet.

2.1.3. Measurements of Tourism Carbon Emissions

Tourism is not a traditional sector of the national economy, and few countries keep separate accounts for its carbon emissions. The lack of data makes estimating tourism carbon emissions reasonably become the groundwork of low-carbon tourism research. Some studies have systematically analyzed tourism carbon emissions by collecting first-hand data on energy consumption through surveys [23,24]. However, the survey research suffers from low response rates and limited sample size, which may make the samples less representative and difficult to reflect the general level of the whole industry. Therefore, the two approaches of "top-down" and "bottom-up" are much more common.

The "bottom-up" analysis divides the tourism industry into different parts (transport, accommodation, and activities) from the consumption side and estimates their carbon emissions separately [25]. While this approach is easy to follow, auditing the carbon emissions produced by each link of the tourist activity remains impractical [26]. Some studies have found that tourism's indirect carbon emissions even exceed its direct carbon emissions [27]. Ignoring indirect carbon emissions may lead to a serious underestimation of tourism carbon emissions.

The "top-down" analysis considers the tourism industry as part of the national economy, estimating tourism carbon emissions at the aggregate level directly. This approach usually requires macro-level input-output data to derive energy consumption in various subsectors of the tourism industry [27,28]. Compared with the former, this approach is able to incorporate indirect carbon emissions in the analytical framework, which makes its accounting boundary more complete. This means that the "top-down" model is able to provide a more comprehensive and accurate picture of tourism carbon emissions.

2.1.4. Influential Factors of Tourism Carbon Emissions

Grossman and Krueger [29] believe that there are three ways in which economic activity can affect the environment: scale growth, structural change and technological revolution. Existing studies have also mostly followed this analytical paradigm, decomposing the influential factors of tourism carbon emissions into three dimensions: scale, structure, and technology. For example, Peng, et al. [30] found that expanding the tourism market, improving industrial structure, and upgrading the technological level can have a positive impact on the environmental performance of tourism. Wu, et al. [31] also share the view that reasonable industrial structure and advanced techniques can contribute to the optimal allocation of tourism resources, hence reducing tourism carbon emissions. Arguably, technological advances are widely recognized as a key driver of tourism's decarbonized development. However, despite advancements in technology that have enhanced energy efficiency within the tourism industry and slowed the growth rate of greenhouse gas emissions, technological progress in tourism remains sluggish. Energy efficiency gains have not kept pace with tourism's increasing carbon emissions. Consequently, these efforts have failed to effectively reverse the ongoing decline in tourism eco-efficiency [32]. In other words, the current technology system within tourism sector is not yet able to offer a practical way for the industry to meet its carbon reduction goals.

2.1.5. Summary

In summary, the existing literature has already provided rich discussions around the consequences of digital transformation, the measurements of tourism carbon emissions and the influential factors of tourism carbon emissions, respectively. But there is still room for further exploration. Firstly, academia holds divergent perspectives regarding the environmental impacts of digital transformation—some emphasize its negative effects while others highlight the positive outcomes. Hence, it is necessary to explore whether digital technologies contribute to sustainability within tourism industry. Secondly, existing research acknowledges that technology in the tourism sector currently falls short in facilitating its low-carbon transition. However, there remains a noticeable gap in research concerning how emerging technologies specifically influence tourism carbon emissions. Undoubtedly, digital transformation has opened up new opportunities for the tourism industry to cut its carbon emissions. This underscores the need for further exploration into the causal relationship between the two. Thirdly, most studies on tourism carbon emissions are based on a macro perspective, leaving gaps in understanding the environmental issues of tourism companies. This can obscure the unique qualities of tourism companies and limit the practical relevance and applicability of the findings.

2.2. Research Hypothesis

2.2.1. Digital Transformation and Company Carbon Intensity

Digital transformation directly influences the carbon intensity of tourism companies through emission reductions and efficiency gains. On the one hand, digital technology enables accurate accounting for carbon emissions. The development of digital platforms provides tourism companies with an alternative for carbon capture, storage, and flow. This enables multi-dimensional monitoring, real-time forecasting, and alarm management of carbon emissions within tourism activities [33]. With the help of digitalization, tourism companies can make precise adjustments to their carbon-reduction strategies at the right time, thus generating positive feedback on carbon reduction. On the other hand, there is evidence that a well-integrated combination of digital technology and tourism can boost the productivity of relevant companies [34]. By utilizing various digital technologies, tourism companies can gain valuable insights into tourists' preferences and needs. These insights enable them to make well-informed business decisions, optimize the allocation of resources, and reduce unnecessary waste. Relying on digital technology, tourism companies can achieve higher economic output with the same scale of inputs, improve the efficiency of tourism resources and energy use, and lead to a significant reduction in carbon intensity. Building on the preceding analysis, the subsequent hypothesis is proposed:

H1: *Digital transformation can reduce carbon intensity in tourism companies.*

2.2.2. Mediating Effect of Managerial Myopia

Managerial myopia refers to the tendency of company management to prioritize projects that offer quick returns and low investment risk [35]. Such myopic managers may even make irrational decisions that sacrifice the company's long-term interests in favor of maximizing short-term financial performance and boosting stock prices [36]. In China, where there are no mandatory regulations for the environmental practices of tourism companies, while improving environmental performance often requires substantial, long-term investment in research and development. The high costs, significant uncertainty, and extended profit cycles associated with these environmental investments can reduce the current financial surplus of tourism companies, leading to pressures from both internal and external sources. As a result, driven by self-interest, myopic managers often make conservative investment decisions. They might prioritize short-term profitability over environmental responsibility, reducing or even terminating green technology investments that could negatively impact the company's immediate financial outcomes. Ultimately, these actions may hinder tourism companies' efforts to reduce carbon emissions.

Information asymmetry is a significant contributor to managerial myopia [37], and digital transformation can effectively mitigate this issue. The improvement of both internal and external information environments presents a novel opportunity for tourism companies to curb speculative behavior by managers at its source. From an internal control perspective, incorporating information technology into business processes allows tourism companies to efficiently integrate and analyze vast amounts of data, thereby enabling managers to transcend cognitive limitations and broaden their investment horizons. Therefore, digital transformation can assist tourism companies in transitioning from "satisfactory decisions" to "optimal decisions" [38]. This shift enables tourism companies to identify and address the low-carbon travel demand accurately, leading to increased environmental investments. From an external supervision perspective, the widespread deployment of digital technology has significantly accelerated the flow speed of information within tourism companies. It can be said that digitalization leads to a standardized and structured output of information, making it increasingly difficult for managers to conceal insider information. Consequently, the information gap between external stakeholders and company management is narrowed. This change brings multiple external pressures—from the government, media, and consumer groups—to more effectively constrain myopic managerial behaviors. As a result, managers are forced to adopt more positive environmental strategies. Hence, it is hypothesized that:

H2: *Digital transformation alleviates managerial myopia, thereby reducing carbon intensity in tourism companies.*

2.2.3. Mediating Effect of Resource Attraction

The transition to full decarbonization is a gradual process. However, in this process, it isn't easy to effectively balance the costs and benefits of companies in the short term. Funding challenges often make it difficult for tourism companies to fully implement their green transformation. Generally, tourism companies are small in scale and have thin profits, making it hard for them to provide adequate and effective guarantees when applying for loans. Especially after 2020, the COVID-19 pandemic has starkly revealed the vulnerabilities of tourism [39]. External investors may withdraw from tourism projects due to concerns about the companies' solvency and operational risks. As a positive response to national strategies, digital transformation serves as a highlight of company operations, generating high-quality signals that are difficult for competitors to replicate. On the one hand, Chinese government places a high value on the intelligent revolution in tourism and has introduced several funding policies to support tourism companies carrying out digital transformation. For example, Liaoning Province provides smart tourist attractions with subsidies totaling half a million yuan. Direct financial subsidies relieve the urgent need for financial support, injecting vitality into the tourism companies' green innovation. On the other hand, companies that heed the country's call are more likely to attract favorable attention from the capital market. Gaining governmental support suggests that the government recognizes the potential value of these companies' projects [40]. This recognition enhances the reputation of tourism companies undergoing digital transformation and signals their strong growth prospects. Spreading positive signals boosts confidence in external stakeholders to invest in these tourism companies, broadening companies' financing channels and providing stable financial support for green innovation activities [10]. Additionally, a good company image makes these companies more appealing to high-quality job seekers [41]. This, in turn, helps to gain the intellectual capital necessary for tourism companies to import and develop clean technologies. The improved human capital structure will continue to escort tourism companies to achieve the green transformation goal [9]. Hence, the third hypothesis is supposed:

H3: *Digital transformation attracts external resources, thereby reducing carbon intensity in tourism companies.*

2.2.4. Mediating Effect of Collaborative Culture

The tourism system has always been complex, involving many areas such as catering, accommodation, and transport [42]. Companies within the tourism chain belong to different sub-sectors, making cross-industry and cross-regional collaboration essential for their survival and growth. Currently, tourism companies are facing a more complicated external environment. As tourism consumption upgrades continuously, market competition is fiercer than ever. Under such a situation, it is clear that no one company can go it alone. Through cloud platforms and other digital tools, the development of tourism company clusters can break the boundaries of time and space, shifting from "geographic agglomeration" to "virtual agglomeration" [43]. Digital sharing platforms break the information barriers between tourism companies and their partners, making it possible to bridge "isolated information islands" and reduce information asymmetry. The reduction of information asymmetry fosters mutual trust [44] and significantly raises the efficiency of collaboration among tourism companies. Enhancing the cooperative awareness of tourism companies will promote their carbon reduction practices. On the one hand, a collaborative culture guides tourism companies to consider common interests. Driven by the goal of maximizing overall profits, they may further increase low-carbon investments [45]. On the other hand, the innovation of green technology is an important component of low-carbon development, while digital transformation can effectively address risk challenges during the innovation process. Collaboration provides tourism companies with access to external knowledge and resources for green innovation, helping to disperse the risks of technological innovation and thereby reducing the trial-and-error costs of green transformation [46]. In the meantime, the existing literature suggests that collaboration has a cross-organizational learning effect, which contributes to the diffusion of knowledge in collaborative networks [47]. Tourism companies can continuously learn from cutting-edge knowledge and technologies through cooperative action. By internalizing these resources into their low-carbon practices, tourism companies will continue to enhance their carbon control and ultimately improve their environmental performance. We thus propose the fourth hypothesis:

H4: *Digital transformation nurtures a culture of collaboration, thereby reducing carbon intensity in tourism companies*.

3. Methodology

3.1. Sample Selection and Data Collection

Chinese A-share listed companies are businesses listed on the Shanghai and Shenzhen stock exchanges. These companies raise capital from public investors through A-shares, which represent ordinary shares available for trading within mainland China. According to the guidance for industry classification of listed companies issued by China Securities Regulatory Commission, we select the companies with the highest proportion of tourism-related revenue relative to their primary business revenue from all A-share listed companies as our research sample. To avoid unnecessary omissions, we further improve the company list by consulting relevant prior literature [48,49]. Notably, Chinese listing rules of shares clearly state that listed companies with abnormal financial status will be subject to special treatment (marked as ST, ST*, or PT by the exchange to warn the investors of the risk). Since these anomalous data are hardly representative of the mainstreaming of tourism companies and may even distort our conclusions, we excluded observations marked with these designations in the current year. Given that the input-output data used to calculate the tourism coefficient was last updated in 2020, the sample period spans from 2005 to 2020. In the end, after removing observations lacking core data, our final dataset includes 478 observations from 39 tourism companies. The company data used to screen the sample were obtained from the CSMAR database.

The macro-level data used herein are primarily from the China Statistical Yearbook, China Energy Statistical Yearbook, Input-Output Tables of China (42 Sectors), China Tourism Statistical Yearbook, and China Tourism Sample Survey Information. The micro-level data are from the CNRDS database, the CSMAR database, and the annual reports published by listed companies. Linear interpolation is used to fill in missing data, which is a common method in business research. Taking the total revenue of “transportation, storage, and postal services” as an example, the specific practices are as follows:

In the Input-Output Tables of China (42 Sectors), this data is updated every 2–3 years. This means that a reasonable handling of missing values is needed to ensure the dataset is complete and valid. Assuming that data changes are continuous between two known data points and can be approximated by a straight line (for example, the total revenue for 2005 is y_1, and the total revenue for 2008 is y_2), we can estimate the value of the unknown point (total revenue in 2007, assumed to be y):

$$\frac{y - y_1}{2007 - 2005} = \frac{y_2 - y_1}{2008 - 2005} \tag{1}$$

$$y = \frac{2}{3}(y_2 - y_1) + y_1 \tag{2}$$

3.2. Variable Definition

3.2.1. Explained Variable

The explained variable is company carbon intensity (*CCI*). Due to the absence of mandatory disclosure requirements for carbon emission data in China, few tourism companies voluntarily disclose relevant information in their annual reports, making it difficult to obtain carbon information directly at the micro level. As noted above, the “top-down” analysis is more feasible and comprehensive than other methods in estimating carbon emissions caused by tourism. Thus, we broadly follow this practice to calculate *CCI*.

Firstly, since there are no separate statistics on tourism energy consumption, we attempt to measure carbon emissions in the tourism industry by utilizing energy consumption data from relative industries. Specifically, according to the industrial classification standard set by the Standardization Administration of the PRC, industries most closely associated with tourism are "transportation, storage, and postal services" and "wholesale and retail trade, accommodation, and catering". However, the energy consumption of these two industries is only partially allocated to tourism activities, which means it needs to be separated from the available statistics by means of tourism coefficient. The tourism coefficient can be computed through the following formula [50]:

$$V_r = \frac{G_r}{D_r} \tag{3}$$

$$T_r = I_r \times V_r \tag{4}$$

$$S_r = \frac{T_r}{G_r} \tag{5}$$

where r denotes the two industries closely related to tourism, including "transportation, storage, and postal services" and "wholesale and retail trade, accommodation, and catering"; G_r denotes the value-added of industry r; D_r denotes the total revenue of industry r; V_r denotes the value-added rate of industry r; I_r denotes the tourism revenue from industry r, provided by the Ministry of Culture and Tourism of PRC in the Tourism Sample Survey Information (including the costs of transportation, post and telecommunications, accommodation, catering, and shopping); T_r denotes the value-added of tourism in industry r. After applying these steps, we ended up with the tourism coefficient S of these two relative industries.

On this basis, referring to Wang, et al. [51], we construct the subsequent equation to evaluate the carbon emissions of the whole tourism industry:

$$carbon\_tour = \sum_{r=2}^{2} \sum_{j=1}^{13} \left(Energy_{rj} \times k_j \times f_j \times S_r \right) \tag{6}$$

where j denotes the types of energy, including raw coal, washed coal, coke, coke oven gas, petrol, kerosene, diesel, fuel oil, liquefied petroleum gas, natural gas, liquefied natural gas, heat, and electricity; $Energy_{rj}$ denotes the jth energy consumed by industry r; k_j denotes the standard coal coefficient of the jth energy; f_j denotes the carbon emission coefficient of the jth energy provided by IPCC [52]; S_r denotes the tourism coefficient of industry r.

Ultimately, drawing on Zhou and Liu [15], we get the carbon intensity index of tourism companies. The formula is as follows:

$$cost\_tour = \sum_{r=2}^{2} cost_r \times S_r \tag{7}$$

$$carbon\_com_{it} = \frac{cost\_com_{it}}{cost\_tour_t} \times carbon\_tour_t \tag{8}$$

$$CCI_{it} = \frac{carbon\_com_{it}}{revenue\_com_{it}} \tag{9}$$

where i and t denote company and year, respectively; $cost_r$ denotes the prime operating cost of the two relative industries; *carbon_tour* denotes the tourism industry carbon emission; *cost_tour* denotes the operating cost of tourism industry; *carbon_com* denotes the tourism company carbon emission; *cost_com* and *revenue_com* denote the operating cost and revenue of tourism companies, respectively.

3.2.2. Explanatory Variable

The core explanatory variable is digital transformation (*DT*). How to scientifically quantify digital transformation is the key question that must be answered to test the previous hypotheses empirically. Drawing on the research of Hu, Fan and Zhang [7] and Huang [53], this paper sums up the feature word frequency of "digital transformation" in the MD&A section of tourism companies' annual reports with the help of Python's "Jieba" package. The total word frequency is logarithmized after adding 1 to combat the positive skew of data. In this way, we finally obtain a reliable measurement index for digital transformation.

3.2.3. Control Variables

To further improve the accuracy of the study, refer to the methods of relevant literature [54,55], this paper includes subsequent control variables: (1) Financial characteristics: asset-liability ratio (*ALR*), company size (*CS*), company age (*CA*), cash flow (*CF*), and company growth (*CG*). (2) Governance characteristics: ownership stability (*OS*), large shareholder expropriation (*LSE*), and dual roles in one (*GMD*). (3) Technical characteristic: R&D expense (*RD1*) and its dummy variable (*RD2*). Table 1 provides a specific statistical description of the variables.

Table 1. Descriptive statistics.

Variables	Obs	Definition	Mean	SD	Min	Max
carbon_tour	16	Refer to 3.2.1	3935.859	2052.552	1562.653	7145.033
carbon_com	478	Refer to 3.2.1	11.896	25.523	0.048	204.592
CCI	478	Refer to 3.2.1	4.693	3.062	0.320	21.981
DT	478	Refer to 3.2.2	1.610	1.257	0.000	5.112
ALR	478	The ratio of total liabilities to total assets.	0.376	0.185	0.025	1.282
CS	478	The natural logarithm of the total assets of the company.	21.645	1.196	18.157	26.847
CA	478	The natural logarithm of the number of years of company inception.	2.846	0.377	0.693	3.526
CF	478	The ratio of cash flow to total assets.	0.061	0.076	−0.447	0.359
CG	478	The growth rate of revenue.	0.729	5.465	−2.897	71.473
OS	478	The difference in shareholding ratio between the top two shareholders.	26.279	16.901	−8.040	67.500
LSE	478	The ratio of other receivables to total assets.	0.035	0.063	0.000	0.508
GMD	478	Dummy variable, which is 1 if the chairman and general manager are combined and 0 otherwise.	0.096	0.295	0.000	1.000
RD1	478	The natural logarithm of R&D, the missing data is replaced by 0.	3.435	6.723	0.000	20.530
RD2	478	Dummy variable, which is 1 if R&D is missing and 0 otherwise.	0.789	0.409	0.000	1.000

As shown in Table 1, with the improvement of people's consumption level, the increasing pressures on carbon reduction have become a constraint for tourism's high-quality development. In addition to carbon emissions plummeting due to the epidemic in 2020, the overall carbon emissions of the tourism industry continue to show an upward trend from 2005 to 2019. Delinking carbon emissions and economic growth in tourism industry is imperative and urgent. Specific to tourism companies, the mean and standard deviation of *CCI* are 11.896 and 25.523, respectively, demonstrating that there are significant differences among tourism companies' carbon emission index. From an industry perspective, in all 478 observations, 118 of them are attractions, 125 of them are hotels or restaurants, 141 of them are travel agencies, and the remainder provide other support services for tourism (such as providing media services for attractions). By comparison, the mean of *carbon_com* of hotels and restaurants (4.871) is much lower than attractions and travel agencies (more than 20), which may lead to a weaker impact of digital transformation on company carbon intensity in hotels and restaurants. This might be because tourism products in China are still dominated by sightseeing tours, making tourists do shorter stays in hotels and restaurants (only for resting and dining). Meanwhile, attractions such as theme parks often require significant energy for entertainment, from operating rides to powering extensive lighting and sound systems, all of which significantly contribute to carbon emissions. Travel agencies often depend heavily on transportation. Moving tourists between attractions contributes to a higher carbon footprint for travel agencies. To eliminate the potential impact caused by industry differences, we further add industry fixed effect to the foundation of the two-way fixed effects model.

3.3. Model Construction

Aiming to examine how digital transformation impacts the carbon intensity in tourism companies, this paper sets and tests the following panel regression model:

$$CCI_{it} = \beta + \beta_1 DT_{it} + \lambda Control_{it} + \delta_i + \mu_t + \eta_j + \varepsilon_{it} \tag{10}$$

where j denotes industry; *Control* denotes the set of company-level control variables; δ_i, μ_t, and η_j denote individual, year, and industry fixed effects, respectively; ε denotes the random error term. To eliminate estimation bias caused by heteroskedasticity and autocorrelation, the standard errors in this paper are clustered at the company level.

4. Empirical Results

4.1. Benchmark Regression

Table 2 shows the regression results of the impact of digital transformation on carbon intensity in tourism companies. The model's coefficient of determination is 0.844, showing that our model fits the data well. Column (1) includes only the core explanatory variables. On this basis, Column (2) further controls for individual, year, and industry fixed effects. Column (3) provides the complete result, incorporating both the fixed effects and all control variables. The results show that the coefficients of *DT* are significantly negative at least at the statistical level of 5%. Whether it includes control variables and fixed effects or not, the fundamental conclusion of this paper remains unchanged. In Column (3), the regression coefficient of digital transformation on company carbon intensity is −0.258. In an economic sense, it means that one unit increase in the *DT* index will make the carbon intensity of tourism firms decrease by 0.258 units. Tourism companies that undergo a greater level of digital transformation tend to exhibit lower levels of carbon intensity, which confirms the significant negative impact of *DT* on *CCI*. H1 is supported.

Among all the control variables, cash flow, company growth, large shareholder expenditure, R&D expense, and its dummy variable on company carbon intensity are significant at least at the statistical level of 10%, indicating that all these factors significantly affect company carbon intensity. More specifically, when cash flow, company growth, R&D expense, and its dummy variable increase by one unit, company carbon intensity will decrease by 3.039, 0.012, 0.243, and 3.711 units, respectively. Conversely, when large shareholder expenditure increases by one unit, company carbon intensity will increase by 5.658 units. It indicates that adequate funding is essential to the carbon reduction of tourism companies.

Table 2. Benchmark regression results.

Variables	**CCI**		
	(1)	**(2)**	**(3)**
DT	−0.638 ***	−0.361 **	−0.258 **
	(0.172)	(0.141)	(0.108)
ALR			0.093
			(0.840)

Table 2. *Cont.*

Variables	**CCI**		
	(1)	**(2)**	**(3)**
CS			0.098
			(0.255)
CA			−0.299
			(1.692)
CF			−3.039 *
			(1.503)
CG			−0.012 *
			(0.007)
OS			0.023
			(0.018)
LSE			5.658 **
			(2.235)
GMD			0.520
			(0.355)
RD1			−0.243 **
			(0.110)
RD2			−3.711 **
			(1.646)
Individual	No	Yes	Yes
Year	No	Yes	Yes
Industry	No	Yes	Yes
Constant	5.721 ***	5.275 ***	6.897
	(0.488)	(0.227)	(8.867)
R-squared	0.069	0.823	0.844
N	478	478	478

Note: Standard errors in parentheses; *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

4.2. Robustness Test

To ensure the reliability of the findings in the previous study, this paper uses the following methods for robustness testing:

1. Substituting variables. In terms of the explanatory variable, considering that the management may overstate the company's digitization level in the annual report for self-interested motives, which leads to the distortion of *DT* constructed previously. To mitigate the potential bias arising from the company's "be all mouth and no trousers", we re-measured digital transformation by using the share of software assets in total assets multiplied by 100, which is labeled as *DIA*. In terms of the explained variable, we chose the natural logarithm of the "E" of the ESG rating index (*ES*) published by CRNDS as a proxy variable for *CCI*. Greater value signifies stronger effectiveness in reducing carbon emissions. As the regression results presented in Columns (1)-(2) of Table 3, the coefficient of *DIA* in column (1) is significantly negative at the 1% level, while the coefficient of *DT* in column (2) is significantly positive. The results suggest that digital transformation still exerts a significant effect on reducing carbon intensity in tourism companies, regardless of the variable measures used. The robustness of the benchmark regression conclusion is supported.

2. Eliminating the interference of the epidemic. The tourism sector was severely struck by the COVID-19 pandemic in 2020. Many companies were forced to close or suspend operations, leading to a significant plunge in their carbon emissions. Ignoring this interference may skew the conclusions of this study. Given this, this study re-estimates the data after excluding the samples in 2020. With the results presented in Column (3) of Table 3, the coefficient for *DT* remains significantly negative, indicating that even after excluding the impact of the epidemic, digital transformation can still significantly curb the carbon intensity of tourism companies.

Table 3. Robustness test.

Variables	CCI	ES	CCI	CCI	CCI	CCI	CCI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DIA	−0.276 ***						
	(0.055)						
DT		0.098 *	−0.227 **	−0.264 **	−0.297 ***	−0.453 *	−0.604 ***
		(0.052)	(0.105)	(0.105)	(0.103)	(0.216)	(0.222)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	12.504 **	−0.158	5.842	−8.671	8.508	−19.314	2.700
	(5.413)	(1.880)	(9.104)	(10.865)	(5.952)	(13.160)	(11.770)
R-squared	0.830	0.568	0.853	0.848	0.889	0.938	0.895
N	327	407	450	438	367	87	214

Note: Standard errors in parentheses; *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

3. Adding potential control variables. In addition to internal company characteristics, external environmental factors may also affect the environmental behaviors of tourism companies. This paper further adds macroeconomic control variables at the city level based on the benchmark regression model, which includes economic development, measured by the logarithm of GDP per capita; economic growth capacity, measured by the GDP growth rate; industrial structure, measured by the proportion of the value-added of the tertiary industry to GDP; and government intervention, measured by the proportion of local financial expenditure to GDP. Column (4) of Table 3 demonstrates that, even after accounting for external factors, the coefficient of *DT* remains significantly negative, suggesting that our core conclusion—the digital transformation of tourism companies dramatically lowers their carbon intensity—has no substantial change.

4. Excluding the strategic behavior. The digitalization-related information in annual reports is dominated by textual information, and the flexibility of text language can potentially leave space for concept hype. To address this, we conducted three tests: (1) excluding non-digitally transformed samples; (2) excluding samples with information disclosure ratings from Shanghai and Shenzhen Stock Exchange lower than 4 (Excellent); and (3) referring to Zhao, et al. [56], excluding samples with residual terms greater than 0 based on constructing a model to calculate the normal frequency of digital transformation disclosures. The sample-adjusted regression results are presented in the last three columns of Table 3. It can be seen that the coefficients of *DT* are all significantly negative from columns (5)–(7), demonstrating the carbon reduction effect of digital transformation is sound and reliable.

4.3. Endogeneity Test

Despite efforts to relieve the impact of unobservable factors by clustering standard errors and adding fixed effects, problems such as reverse causality and omitted variables still persist. Tourism companies with higher environmental awareness might be more inclined to pursue digital opportunities, driven by their burning desire to enhance decision-making, improve information flow, and foster innovation [57]. At the same time, due to the limited number of control variables in the model, not all influential factors can be included. The omission of potential variables may lead to biased coefficient estimates. To further identify the causal relationship between variables, this paper introduces two instrumental variables: (1) the average of *DT* by the province in the same year (*iv1*), and (2) the interaction term between the cities' relief degree of land surface and the logarithm of China's internet users (*iv2*). The result of the two-stage least squares regression is presented in Table 4. The Kleibergen-Paap rk LM statistic rejects the null hypothesis at the 1% significance level and the Cragg-Donald Wald F-statistic is 152.926. Both the results confirm the validity and reliability of the selected instrumental variables. Since the number of the core explanatory variable is less than the instrumental variable, we further perform the overidentification test. The *p*-value for the Hansen J test is 0.374, suggesting both instrumental variables are exogenous. As shown in Columns (1)–(2), the coefficient of *DT* remains significantly negative at the 10% level after addressing possible endogenous problems, which indicates benchmark regression results are robust.

Table 4. Instrumental variables regression result.

Variables	**The First Stage: DT**	**The Second Stage: CCI**
	(1)	**(2)**
iv1	0.896 ***	
	(0.057)	
iv2	0.129 ***	
	(0.047)	
DT		−0.301 *
		(0.166)
Control	Yes	Yes
Individual	Yes	Yes
year	Yes	Yes
industry	Yes	Yes
Kleibergen-Paap rk LM stat.	18.141 ***	
Cragg-Donald Wald F stat.	152.926	
Hansen J stat.	0.789	
(P)	(0.374)	
N	478	

Note: Standard errors in parentheses; *, *** represent statistical significance at the 10% and 1% levels, respectively.

5. Further Discussion

5.1. Mediating Effect Analysis

According to the previous theoretical analysis, digital transformation has an informational effect that can reduce tourism company carbon intensity by alleviating managerial myopia, attracting external resources, and nurturing a collaborative culture. Referring to Liu, et al. [58], we set the following model to identify these three potential mechanisms:

$$Mediator_{it} = \gamma + \gamma_1 DT_{it} + \lambda Control_{it} + \delta_i + \mu_t + \eta_j + \varepsilon_{it} \tag{11}$$

where *Mediator* denotes the mechanism variable, including managerial myopia (*MM*), resource attraction (*RA*), and collaborative culture (*CC*). The remaining symbols have the same meanings as previously described.

First, in order to verify whether digital transformation alleviates managerial myopia, referring to the methodology of Hu, et al. [59], we summarize the frequency of keywords in MD&A disclosure with the help of a lexicon that characterizes myopic behavior. Subsequently, we divide the total myopic word frequency by the total words of MD&A and multiply it by 100 to measure managerial myopia. The larger indicator value suggests that managers prefer a myopic choice in decision-making. As the regression results presented in Column (1) of Table 5 show, the estimated coefficient of *DT* is significantly negative at the 5% level, indicating digital transformation can effectively reduce managers' myopic propensity. Column (2) further tests the impact of managerial myopia on company carbon intensity. The results demonstrate that the coefficient of *MM* is significantly positive, which means there is a significant positive correlation between managerial myopia and company carbon intensity. Thus, digital transformation can reduce tourism companies' carbon intensity by alleviating managerial myopia, and H2 is verified.

Table 5. Mechanism test results.

Variables	MM	CCI	RA	CCI	CC	CCI
	(1)	(2)	(3)	(4)	(5)	(6)
DT	−0.022 **		0.014 *		0.249 ***	
	(0.009)		(0.008)		(0.042)	
MM		2.006 ***				
		(0.732)				
RA				−0.830 *		
				(0.454)		
CC						−0.572 ***
						(0.201)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.221	6.004	0.153	6.505	1.324	7.411
	(0.438)	(8.789)	(0.348)	(9.297)	(1.570)	(8.594)
R-squared	0.381	0.845	0.492	0.842	0.787	0.848
N	478	478	478	478	478	478

Note: Standard errors in parentheses; *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

Second, from the dimensions of government, financial, and human resources, this paper selects three individual indicators—the proportion of government subsidies, the KZ index, and the proportion of highly skilled (hold a bachelor's degree or higher) employees—to measure *RA* using the entropy weight method. The results are reported in Columns (3)–(4) of Table 5, showing that the coefficients of *DT* and *RA* are 0.014 and −0.830, respectively. Both the coefficients pass the significance test at the 10% level and their signs are consistent with the theoretical expectation. The results show that the positive signal sent by digital transformation channels more external resources to the tourism companies, easing their plight of resource constraints, so as to assist companies' projects of green transformation to fall on the ground. Thus, digital transformation can reduce tourism companies' carbon intensity by attracting external resources, and H3 is verified.

Third, a company's annual report is more than just a compilation of statistics to demonstrate how it operates. It is also a showcase of corporate values. Therefore, this paper refers to Li, et al. [60] and Bai, et al. [61] to logarithmize the total word frequency related to "collaboration" in the annual reports after adding 1 by which to measure a company's collaborative culture. The results are shown in the last two columns of Table 5. The regression coefficient of *DT* in Column (5) is significantly positive at the 1% level, implying that digital transformation can significantly enhance the collaborative culture in tourism companies. Further, the results in Column (6) show that the coefficient of *CC* is significantly negative at the 1% level, verifying the negative relationship between collaborative culture and company carbon intensity. The findings show that digital transformation helps in the cultivation of a collaborative culture in tourism companies, creating fertile ground for collaborative research in carbon reduction across the entire tourism industrial chain, which will ultimately improve tourism companies' environmental performance, and H4 is supported.

5.2. Heterogeneity Analysis

5.2.1. Company Ownership Heterogeneity

The ownership property of state-owned companies underpins their inherent political connections with government agencies. These companies often act in alignment with the state will and are more likely to respond to government environmental initiatives. We divide the samples into two groups: private and state-owned. The grouped regression results for company ownership are provided in Columns (1)–(2) of Table 6. It shows that digital transformation significantly reduces state-owned companies' carbon intensity, while the estimated coefficient of *DT* for private companies is insignificant. A possible explanation for such a phenomenon is that the foundation of private tourism companies is generally weak, which makes it difficult for them to solve the bottlenecks constraining their digital transformation. In contrast, state-owned companies enjoy more preferential policies in obtaining loans and resources [62]. The long-term and stable financial support addresses their worries about digitization. In addition, state-owned companies also commit themselves to more social responsibility, which impels them to improve their environmental behavior by introducing clean technologies. Consequently, state-owned tourism companies experience a more significant impact on carbon emission reduction through digital transformation compared to their private counterparts.

Table 6. Heterogeneity analysis results.

Variables	CCI					
	Private	**State-Owned**	**Low Diversity**	**High Diversity**	**Low-Level Business Environment**	**High-Level Business Environment**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
DT	0.093	−0.314 **	−0.166	−0.425 ***	−0.185	−0.330 **
	(0.207)	(0.139)	(0.176)	(0.135)	(0.146)	(0.132)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Constant	34.841	4.627	13.057 **	6.662	−16.680	7.646
	(40.201)	(9.030)	(5.481)	(18.167)	(12.846)	(6.454)
R-squared	0.839	0.887	0.894	0.849	0.861	0.864
N	129	349	207	240	216	262

Note: Standard errors in parentheses; **, *** represent statistical significance at the 5%, and 1% levels, respectively.

5.2.2. Board Diversity Heterogeneity

From the corporate governance perspective, board characteristics may significantly influence the decision-making process regarding digital transformation. A diverse board, with members from various industry backgrounds, can expand access to resources, promote knowledge exchange across different fields, and help tourism companies make more informed strategic choices by avoiding groupthink. So, the impact of digital transformation on reducing carbon intensity is more pronounced in companies with diverse board industry backgrounds. To assess this, we employ the Blau index [63], a common metric for evaluating group diversity, to measure the diversity of industry backgrounds among board members in tourism companies, calculated as:

$$Blau = 1 - \sum_{k=1}^{n} {P_k}^2 \quad (12)$$

where P_k denotes the percentage of board members from the kth industry background. The Blau index ranges from 0 to 1, with a higher index indicating the greater diversity of industry backgrounds. Based on this, the samples are grouped according to the annual median of *Blau*. The heterogeneity regression results are presented in Columns (3)–(4) of Table 6. The estimated coefficient of *DT* is significant at the 1% level in companies with high board industry-background diversity, whereas it is not significant in the low-diversity group. This means boards with diverse industry backgrounds effectively synthesize varied ideas, opinions, and skills, deepening their understanding of the evolving internal and external environment. Accordingly, the diverse board team helps to strengthen the quality and effectiveness of the supervision over management, effectively suppresses the speculative tendency of myopic managers, and thus translates environmental commitments into concrete actions. As a result, the effect of digital transformation on reducing carbon intensity is more pronounced in tourism companies with higher board diversity in industry background.

5.2.3. Business Environment Heterogeneity

The business environment is a comprehensive ecosystem comprising various external factors that may affect business operations. As important entities in such a system, companies' strategic choices are inevitably influenced by the business environment in which they operate. Drawing on the approaches of Guo, et al. [64], we choose relevant indicators from the four dimensions to measure a city's business environment index, including: (1) Economic environment: per capita GDP, GDP growth, final consumption expenditure as a share of GDP, and average wage of employees. (2) Market environment: total exports and imports as a share of GDP, loans as a share of GDP, number of employees, and total factor productivity. (3) Infrastructure: total passenger traffic, road area per capita, and electricity consumption. (4) Policy environment: local general public budget expenditure and taxes on main operations as a share of profit. On this basis, this paper applies the entropy weight approach to generate an integrated score to assess the business environment. Similarly, the samples are categorized into different groups depending on the annual median, and the regression results are shown in the last two columns of Table 6. As can be seen, the impact of digital transformation on carbon intensity is significantly negative among tourism companies in cities with high-level business environments, while the coefficient is not significant for the low-level group. This could be due to the favorable business environment providing a solid institutional and material guarantee for companies' digital transformation: a good business environment usually has a strict intellectual property protection system, which stimulates digital innovation within tourism companies [65]. Moreover, business environment optimization generally implies a systematic and complete infrastructure system. The strong infrastructure base provides the underlying support for the efficient flow of innovation factors [66], lowering the transformation costs of tourism companies. Additionally, a dynamic and open business environment encourages intense market competition. The compression of profit margins pressures tourism companies to fulfill their environmental responsibilities, securing more external support by responding to social expectations. Therefore, the negative impact of digital transformation on company carbon intensity is more significant in the high-level business environment group.

6. Conclusions and Implications

Building on digitalization and greenization, two main themes of the times, this paper constructs a panel regression model with the use of data on Chinese A-share listed tourism companies from 2005 to 2020, analyzing the impact of digital transformation on tourism companies' carbon intensity from both theoretical and empirical dimensions for the first time. This paper concludes that: First, the digital transformation of tourism companies dramatically lowers their carbon intensity. Several robustness and endogeneity tests show that this conclusion is stable. Second, further mediating effect analysis shows that digital transformation optimizes tourism companies' information environments, which contributes to alleviating managerial myopia, attracting external resources, and fostering a collaborative culture so as to produce a carbon emission reduction effect in tourism companies. Third, the heterogeneity tests reveal the effectiveness of digital transformation on company carbon intensity varies under different internal and external circumstances. Internally, such an impact is more noticeable in SOEs or tourism companies with diverse board industry backgrounds. Externally, a better business environment means stronger inhibition of digital transformation on tourism companies' carbon intensity.

6.1. Theoretical Implications

Different from the common paradigm of previous studies, this paper attempts to extend the analysis to the company level for the first time, responding to the academic appeal for further refining the scale of tourism carbon research [3]. Based on previous literature about the consequences of digital transformation and combined with the characteristics of tourism companies, this paper explores the influence paths between digital transformation and company carbon intensity with an informational effect viewpoint. This provides valuable insight for tourism companies to fully leverage digital transformation as the engine in driving low-carbon development. Additionally, out of concern for different internal and external conditions, this paper conducts a series of heterogeneity analyses to strengthen the causal link between digital transformation and company carbon intensity, which provides theoretical support for governments and tourism companies in formulating their strategies.

6.2. Practical Implications

First, this paper lays the theoretical groundwork for tourism companies to proactively embrace digital transformation. In the context of social development, climate change remains a deep concern for the international community. Achieving the ambitious goal of dual carbon is a shared focus across various sectors of society. Our study examines how digital transformation in tourism companies can contribute to carbon emission reductions, providing a pathway option for them to achieve decarbonization.

Second, this paper offers policy recommendations for the government to guide tourism companies toward high-quality development. Businesses now have more chances to achieve sustainable development as the digital economy grows in importance as a driver of economic growth. This involves the dual objectives of economic development and environmental preservation, which need to be balanced and pursued in tandem. By examining the relationship between digital transformation and carbon emissions in the tourism sector, this paper outlines a new approach for the government to promote industry upgrades and steer the tourism economy toward healthy growth.

6.3. Managerial Implications

The findings of this paper are instructive for tourism companies by leveraging digital transformation to achieve decarbonization transition:

First, digital transformation is an important engine for reducing carbon emissions in parallel with expanding green transition for all tourism companies. Tourism companies need to develop a sound perception of digitalization and actively respond to the initiative of carbon neutrality. The right choice is developing a scientific strategy and proactively seeking transformation opportunities. By leveraging digital tools, tourism companies can establish a carbon management system, which allows for dynamic monitoring and analysis of energy consumption during tourism activities. With these approaches, tourism companies can further unlock the green potential of digital transformation to drive carbon reduction through the comprehensive integration of digital technologies and business operations.

Second, alleviating managerial myopia, attracting external resources, and fostering a collaborative culture are the key channels to maximize the positive effect of digital transformation in reducing tourism companies' carbon emissions. Tourism companies need to attach greater emphasis to the value of digital transformation in improving the information environment. Tourism companies should bring in digital analysis tools, integrate various data sources and facilitate a comprehensive upgrade in internal control. Through the shift from "experience-driven" to "data-driven", tourism companies can minimize myopic managerial decision-making and further increase investment in low-carbon transformation. Moreover, tourism companies should consistently release positive signals of digital transformation, using digital technologies to enhance their management capabilities while optimizing business models. By showcasing their proactive efforts and positive growth, these companies can attract external support, converting it into a driving force for decarbonization. Finally, to overcome the innovation deficiency, tourism companies should also place greater emphasis on collaboration during their digital transformation, foster digital ecosystems with partners, and enable the open sharing of experiences and resources. For instance, Ctrip, a leading online travel agency in China, has used its strong digital presence to collaborate extensively with eco-partners. Through initiatives such as developing an industry carbon standard, setting an environmental threshold, and strengthening cross-border collaboration, Ctrip has explored viable pathways to reduce carbon emissions and promote sustainable practices across the tourism industry. These approaches encourage more tourism companies to engage in environmental protection efforts.

Third, the results of the heterogeneity analysis indicate that both internal and external characteristics of tourism companies can make a huge difference to the carbon reduction benefit of digital transformation. Appointing board members with backgrounds in a range of industries would help tourism companies bring in various knowledge and skills. This allows companies to think through and develop a holistic plan for digital transformation from many angles. By doing so, the board's regulatory role will be fully unlocked, and the risk of transformation failure will be decreased. Thus, tourism companies should assemble a diverse board of directors to amplify the positive effects of digital transformation for carbon reduction. Furthermore, the government ought to give due consideration to the practical needs of private companies, augment its assistance for the digital conversion of private tourism companies, and resolve the dilemma faced by private tourism companies that "cannot transform, do not transform, and dare not transform". It is necessary to strengthen policy guidelines, establish special subsidies, and support school-enterprise alliances. Simultaneously, government departments should give greater priority to optimizing the urban business environment. A stable, open, and fair business environment requires an overall plan and tailored policies. By increasing financial support, stimulating market vitality, reasonable distribution of digital infrastructure, and promoting the reform in simplifying administration and delegating power, the government and the market can achieve mutual benefit and coexistence, which can provide strong support for "digitization driving greenization".

6.4. Limitations and Future Research

It is worth noting that this paper at least has the following limitations: (1) Although we try to allocate the carbon emissions of the whole tourism sector to each company through a series of calculations, this approach still is a very liberal estimate. We hereby call on more tourism companies to publicize carbon emission data voluntarily, which will directly enhance the accuracy and reliability of the research conclusions. (2) Limited by the availability of data, our sample is merely comprised of 39 Chinese A-share listed tourism companies. Future research could incorporate other data sources and include more small tourism businesses in the research framework to conduct a more in-depth investigation. (3) This paper mainly proposes the impact mechanism of digital transformation on the carbon intensity of tourism enterprises based on the perspective of information asymmetry. In the future, this theoretical system can be expanded and improved by combining other theories.

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