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The Nexus Between Foreign Direct Investment, Green Taxation, Green Technological Innovation, and the Low-Carbon Development in China's Tourism Sector

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Abstract: Foreign direct investment (FDI) serves as a pivotal external driver for the low-carbon transition in developing host countries. However, its environmental impact remains theoretically contested between the "pollution halo" and "pollution haven" hypotheses. This study investigates the nonlinear relationship between FDI and the low-carbon development in tourism (LCDT), with a particular focus on the moderating roles of green taxation (GTAX) and green technological innovation (GTI). The empirical findings reveal that (1) FDI, GTAX, and GTI each significantly promote the LCDT; (2) GTI positively moderates the relationship between FDI and LCDT, whereas GTAX exhibits a negative moderating effect; and (3) these moderating effects demonstrate regional heterogeneities. Theoretically, this research extends the environmental impact literature of FDI to the service sector and uncovers the multifaceted mechanisms driving LCDT. Practically, it offers a scientific basis for guiding the refined design and adjustment of GTAX policies, optimizing regional low-carbon governance plans, thereby supporting China's tourism sector in leveraging opportunities from the restructuring of global green supply chains.

Keywords: foreign direct investment, low-carbon development in tourism, green taxation, green technological innovation, heterogeneity

1. Introduction

In recent years, the world has formed a general consensus on achieving carbon neutrality and sustainable development. Major international organizations like the UN, World Bank, and IEA have initiated a number of key frameworks and initiatives that are essential in facilitating the green transition [1]. COP29 in 2024 was concerned with energy transition, carbon markets, and climate finance, among other things [2]. COP16 paid close attention to the connection between preserving ecosystems, maintaining tourism, and having a low-carbon economy, which is important for the world to look into how tourism will be transformed in the future, which carries both an economic benefit and has environmental importance [3].

Against this background, China has incorporated green and low-carbon principles into the national strategy and has implemented a set of policies—including green taxation (GTAX) and cleaner production—targeting key sectors, such as tourism [4]. The government puts a particular stress on reinforcing ecological compensation and refining green fiscal systems and helps the environmentally vulnerable industries such as tourism to undertake a low-carbon transition. And green development indicators are embedded into regional performance evaluation systems to strengthen the accountability and effectiveness of policies [5]. The National Action Plan for Green Tourism promotes low-carbon projects, clean energy usage, zero-carbon demonstration zones, and the merging of green tech, carbon accounting, and international sustainability certification [6].

Since China initiated its reform and opening-door policy, foreign direct investment (FDI) has offered essential financial resources, but it has also had a catalytic effect on low-carbon development in tourism (LCDT) via green technology spillovers and the adoption of superior management techniques [7]. Empirical studies have found that FDI helps to localize green technologies, which can improve environmental performance and achieve better energy efficiency and emissions reduction results [8]. Also, the better environmental standards held by foreign investment companies have urged domestic companies to boost their green governance skills [9]. Therefore, it is important to get a deeper understanding of the pathways through which FDI impacts resource allocation, technological diffusion, and green transformation in order to realize LCDT [10].

Moreover, GTAX and green technological innovation (GTI) play key roles in driving LCDT. On the one hand, GTAX can encourage high-emission tourism companies to improve

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their environmental compliance, increase the willingness of high-emission tourism companies to use green technology, save energy, and promote the green transformation of high-emission tourism companies [11]. Well-designed GTAX systems can also be proven to greatly improve firms' green total factor productivity, guiding tourism and other services toward high-quality, low-carbon development [12]. On the contrary, GTI provides support for LCDT, especially in urban tourism destinations, where such an innovation helps to increase efficiency and reduce carbon emissions [13]. In addition, the integration of green digital technology and green human resources management can also achieve the green upgrade of tourism.

To further expand on the analytical framework, this research adds GTAX and GTI as moderating variables to investigate the effects of FDI on LCDT. Hence, the research questions for the study are:

1) Does FDI promote LCDT?

   To find out if and how FDI impacts LCDT progress.

2) Are GTAX and GTI independent of LCDT?

   To explore if GTAX and GTI progress could directly drive LCDT through financial incentives and eco-innovation.

3) Through what channels do GTAX and GTI affect LCDT?

   Investigating the moderating role of GTAX and GTI in the FDI–LCDT relationship and whether strong GTAX and GTI capacity can amplify or offset the effect of FDI on LCDT.

4) Do the above relationships have heterogeneity between different levels of development and geographical characteristics?

   It examines the differences in the strength and direction of the above relationships among different regions, reflecting the differences in economic structure, resources, and environmental policy implementation.

The key contributions of the work are:

First, it builds an analytical framework integrating FDI, GTAX, and GTI to analyze LCDT. Through an examination of the moderating effects of GTAX and GTI over and above the simple effect of FDI, the study provides an enhanced understanding of the role that capital flows, fiscal inducements, and technological innovation play collectively in facilitating sustainable change in tourism.

Second, from the methodological point of view, this paper adopts both the moderation model and threshold model to catch the nonlinear and region-specific effects of GTAX and GTI on the FDI–LCDT. This two-pronged strategy improves the strength and explanatory capacity of the findings and also extends the methodological toolbox to analyze intricate policy–investment–environment interactions in green finance, tourism economics, and sustainable development.

Third, this study shows that there is significant regional heterogeneity in the impact of FDI on LCDT, and the effect is stronger in regions with higher green innovation capacity and more effective GTAX implementation. It supports the regional-specific GTAX refinement, green transformation driven by innovation, and improving environmental governance, and it helps to reduce the disparity of green development among different regions.

2. Literature Review

2.1. FDI and LCDT

With China's commitment to its "dual carbon" goals, the tourism industry is undergoing a low-carbon transition. Being a high-energy consumption industry that covers transportation, accommodation, and the operation of scenic areas, tourism produces about 8% of global carbon emissions. This is a significant barrier toward realizing "dual carbon" goals [3]. Promoting LCDT is not only energy-efficient and reduces the environmental burden, but it also aligns with the trend of going green around the world and enhances China's international tourism competitiveness.

In the process of LCDT, FDI plays an important role in terms of a mechanism to optimize resource allocation and facilitate cross-border flow of technological and managerial input. On the one hand, FDI brings low-carbon technologies and management practices and conforms to green standards to enhance firms' global value chain participation and provide technical and institutional support, directly promoting LCDT [14]. But on the contrary, FDI makes firms actively internalize international environmental rules, strengthen environmental responsibilities, and cultivate green innovation ability. And these enhancements boost international competitiveness and foster the LCDT [8].

Furthermore, a considerable number of studies support the positive effect of FDI on LCDT. Sun and Hasi [15] claimed that FDI not only drives domestic firms to upgrade technology but also helps improve the environment of domestic firms indirectly. Shi et al. [16] found out through empirical studies that FDI greatly improves a company's green innovation output, and these effects are even more pronounced in the service sector. Wang and Shao [17] point out that Chinese tourism enterprises have successfully absorbed advanced low-carbon management experiences from investments in developed countries and then localized them for domestic promotion. In addition, Cheng and Qi [18] stressed that FDI has a better effect in transferring greener technology and managerial experience in the sectors with urgent low-carbon transformation needs, such as tourism, which can provide support for sustainable development.

Taken together, the findings imply that FDI makes a contribution both to green transformation on a micro-level and to the effective allocation of low-carbon development resources on a macro-level.

Based on the above analysis, this study hypothesizes that:

H1: FDI can promote LCDT.

2.2. GTAX, FDI, and LCDT

Although FDI is a benefit for LCDT, it depends on the green financial instruments available to be directed at sustainable sectors. Over the last several years, green finance has become a major way to move money toward clean energy changes and good tourism plans [19]. Quantitative studies indicate that green finance, along with renewable energy and technological innovation, can promote sustainable tourism by lowering the carbon intensity and improving the energy efficiency of tourism infrastructure [20, 21]. Yet the degree to which green finance does impact low-carbon results is also dependent upon the extent to which fiscal and regulatory means like GTAX form companies' inducements and investment activity.

GTAX, being a policy tool combining economic disincentives and environmental guidance, is becoming an important instrument to promote sustainable development [22, 23]. It can be seen from the following points. First, GTAX can send out clear price signals to increase the costs of high-emission activities, which promotes more efficient resource allocation [23]. Second, it offers economic rewards to businesses to carry out green innovation, which can promote the advancement of technology and the upgrade of industries [24]. Third, GTAX encourages moving

toward sustainable industrial development models; in the end, it improves the environmental performance of the economy [25]. Lastly, funneling tax money toward the development of green infrastructure and environmental conservation projects, it creates a positive feedback system, which promotes long-term sustainability aims [26].

During the promotion of LCDT, GTAX has become a key policy instrument by internalizing environmental costs and promoting enterprises to accelerate low-carbon transformation. According to the Porter hypothesis, well-designed environmental regulations like GTAX could promote technology innovations, which might increase the positive effects of FDI on LCDT. Tourism contains many high-emission parts such as transportation, lodging, and the operation of scenic areas, so fiscal incentives can encourage companies to use energy-saving technology, adjust their energy structure, and improve carbon efficiency [27]. Especially in environmental taxes and carbon taxes, GTAX can indirectly encourage the certification of environmental labels and green consumption standards, which can promote low-carbon governance and green branding in the tourism sector [28].

A lot of practical proof stresses the benefit of GTAX, at once improving the economy and protecting the environment. Wang et al. [29] found that China's carbon and energy tax policies have greatly improved the energy efficiency of hotel and scenic spot operations. Qamruzzaman [30] provided evidence that environmental taxes curbed carbon emissions and fostered green innovation. In addition, Jabeen et al. [31] use data from G7 countries from 1994 to 2020 and found that environmental taxes have a positive impact on low-carbon development by reducing greenhouse gases and improving the environment.

Based on the above analysis, this study hypothesizes that:

H2: GTAX can promote LCDT.

In recent years, China's GTAX system has been continuously improved under the environmental "fee-to-tax" reform, effectively guiding FDI toward green industries [32]. Research has proved that GTAX, green finance, and GTI can reduce carbon emissions [9].

GTAX has a constraining effect on cost beyond that. GTAX also has a screening and incentive effect. A stable tax regime will send clear signals about environmental governance to foreign investors, attracting those with green technology and a good environmental responsibility [33] to invest in these green tourism projects. Also, increasing the operational costs of high-carbon activities and combining tax credits with green subsidies increases the economic benefits of green investments [34]. Empirical evidence also shows that environmental tax reform has increased the amount of FDI inflow and increased foreign investors' willingness to invest in low-carbon projects [32]. Therefore, GTAX is expected to play a considerable moderating role between FDI and LCDT.

Based on the above analysis, this study hypothesizes that:

H3: GTAX can positively moderate the impact of FDI on LCDT.

Also, an increasing amount of literature indicates that the moderating effect is not linear but has a threshold and asymmetrical effect [35]. Moderate levels of GTAX may stimulate green investment, but excessive taxes can deter foreign capital inflows, especially in sectors with long payback periods and high policy sensitivity like tourism [36]. Li and Liu [37] found that the positive effect of FDI on green performance is greatest at an urbanization rate between moderate levels, indicating an "optimal bandwidth" for the environment.

The tourism industry is capital-intensive, high-risk, and long investment return cycle. Therefore, it is especially sensitive to GTAX. If the tax policies are poorly designed, this would increase the foreign investors' concerns of policy uncertainties, which could result in less likelihood for them to want to invest [38]. So the GTAX system has to take into account the possibility of nonlinear moderating effects on FDI.

Based on the above analysis, this study hypothesizes that:

H4: The moderating effect of GTAX on the relationship between FDI and LCDT is also a nonlinear threshold, and as GTAX increases from a lower threshold to a higher threshold, the moderating effect of FDI on LCDT will gradually weaken.

2.3. GTI, FDI, and LCDT

In addition to fiscal mechanisms like GTAX, GTI's capacity has an important moderating effect on the extent to which FDI is conducive to LCDT. GTI within the scope of ecological modernization is about updating and altering the ordinary technologies to improve resource efficiency and lessen environmental damage [39]. Unlike just increasing productivity, it puts more stress on environmental compatibility, eco-efficiency, and sustainable use of resources [40]. These innovations are especially important for the tourism industry, which is both energy-intensive and highly sensitive to environmental impact. As the world becomes more concerned about climate change and the depletion of resources, GTI is becoming more important for LCDT. It provides new ways to be sustainable and last a long time [41].

The tourism sector has been improved by GTI in terms of environmental quality in tourism-intensive places through reducing energy use and transport emissions [42]. By using panel data from 15 of the world's most popular tourist locations, Avcı et al. [43] discovered that there is a considerable negative association between GTI and tourism-related carbon emissions, which is also supported by two-way causality. GTI is higher in regions that can use green finance better for sustainable tourism and urban low-carbon [44]. Additionally, the use of GTI in tourism includes the use of renewable energy sources, integration of intelligent energy management systems, and use of sustainable building materials to contribute to advancing the LCDT [43].

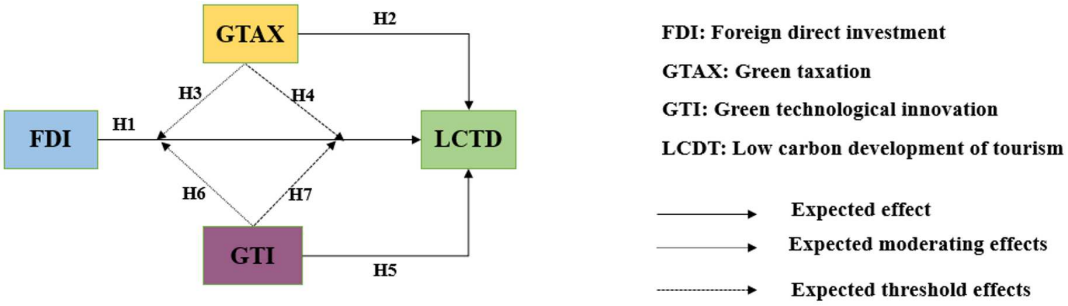
GTI might well show quite obvious performance in cutting back on carbon emission levels inside a specific sector like tourism, and though it takes a certain direction while moving forward, it surely doesn't mean that everything about its behavior stays as direct or one-way thing only [45]. On the one hand, GTI encourages a reduction in emissions and efficiency in resources, which improves environmental sustainability. On the other hand, it might produce a green rebound impact in which decreased operational expenses boost tourism, thereby partially nullifying environmental benefits [46]. However, a considerable amount of empirical evidence suggests that GTI does have a positive effect on LCDT. Kayani et al. [47], in analyzing the BRICS nations, pinpointed that technological advances and the use of renewable energy were important drivers for decreasing emissions in the tourism-related areas. Moreover, FDI and GTI's synergy is worthy of notice. Capital infusion is not the only thing FDI does; it also enables the transnational movement of green technology, and this is very important for making environmentally friendly improvements to tourism infrastructure, especially in developing economies [48]. In this way, the GTI becomes more strategically relevant in advancing LCDT.

Based on the above analysis, this study hypothesizes that:

H5: GTI can promote the LCDT.

Based on the above analysis, FDI can also positively affect LCDT through several channels, such as the introduction of advanced technologies and optimizing resource allocation [49, 50].

Figure 1
Conceptual framework of the impact mechanism



FDI can better push for lower carbon development when GTI is in place, both reducing environmental damage and improving efficiency. However, there is an inconclusive empirical finding about the sustainability outcomes of FDI. On the one hand, FDI could speed up the green shift of tourism. On the other hand, in some areas, it is not as good for the environment. These discrepancies are mainly due to different institutional enforcement levels, varying degrees of technology absorption capacity, and the strictness of environmental regulations [51]. Therefore, the GTI effects of FDI are very context dependent and should be considered along with the other important moderating factors [52].

Among different moderating factors, GTI is an endogenous firm- or region-level capability that is increasingly acknowledged to be a significant moderating mechanism for the environmental impacts of FDI. Existing studies show that GTI can not only reduce the possible negative environmental externalities of FDI but also enhance the ecological benefits of FDI [49]. The relationship between FDI and GTI is not always linear; only after a certain threshold in the level of urbanization do the adverse effects of FDI begin to decrease and synergistic green effects appear [37]. Second, under a more conducive institutional environment and a higher degree of marketization, FDI promotes GTI more effectively; this further confirms the intermediary function of GTI between FDI and low-carbon development [49].

Thus, this study makes the following hypothesis:

H6: GTI can positively moderate the relationship between FDI and LCDT.

H7: The moderating effect is nonlinear, as GTI advances from lower to higher threshold levels, the moderating impact of FDI on LCDT progressively strengthens.

The conceptual framework of the study is presented in Figure 1. In the figure, the dashed arrows denote possible moderating and threshold effects; dashed boxes stand for the relevant moderating and threshold variables.

3. Econometric Model and Data

3.1. Econometric model

This paper will adopt a panel threshold regression model with a double fixed effect to investigate the impact of FDI, GTAX, and GTI on LCDT. The model also tests the moderating roles of GTAX and GTI within this relationship. Given regional heterogeneity in economic development and institutional contexts, sub-sample regressions are conducted to further explore spatial differences.

To test Hypotheses H1, H2, and H5, the following models (1)–(3) are constructed:

$$\mathrm{LCDT}_{it} = a_0 + a_1\mathrm{FDI}_{it} + a_2\mathrm{Control}_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (1)$$

$$\mathrm{LCDT}_{it} = \beta_0 + \beta_1\mathrm{GTAX}_{it} + \beta_2\mathrm{Control}_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (2)$$

$$\mathrm{LCDT}_{it} = \gamma_0 + \gamma_1\mathrm{GTI}_{it} + \gamma_2\mathrm{Control}_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (3)$$

Here LCDTit stands for the level of LCDT in province i at time t, FDIit stands for FDI, GTAXit stands for GTAX, and GTIit stands for GTI. Controlit is a vector containing social consumption levels, fiscal expenditure, environmental regulation, and degree of openness; δi and σt are individual/province and time fixed effects, respectively, and εit is an error term.

To test Hypotheses H3 and H6, this paper will further establish the following models (4)–(5).

$$\mathrm{LCDT}_{it} = \mu_0 + \mu_1\mathrm{FDI}_{it} + \mu_2\mathrm{GTAX}_{it} + \mu_3\mathrm{FDI}_{it} * \mathrm{GTAX}_{it} + \mu_4\mathrm{Control}_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (4)$$

$$\mathrm{LCDT}_{it} = \rho_0 + \rho_1\mathrm{FDI}_{it} + \rho_2\mathrm{GTI}_{it} + \rho_3\mathrm{FDI}_{it} * \mathrm{GTI}_{it} + \rho_4\mathrm{Control}_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (5)$$

Here μ_3 and ρ_3 indicate the direction of the moderating effects. δ_i is the individual fixed effect, σ_t is the time fixed effect, and ε_{it} is the random error term.

In order to test H4 and H7, according to [53], this study constructs the following single-threshold regression methods (6)–(7).

$$\mathrm{LCDT}_{it} = \vartheta_0 + \vartheta_1\mathrm{FDI}_{it} * \mathrm{I}(\mathrm{GTAX}_{it} \le \gamma) + \vartheta_2\mathrm{FDI}_{it} * \mathrm{I}(\mathrm{GTAX}_{it} > \gamma) + \vartheta_3\mathrm{Control}_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (6)$$

$$\mathrm{LCDT}_{it} = \varphi_0 + \varphi_1\mathrm{FDI}_{it} * \mathrm{I}(\mathrm{GTI}_{it} \le \gamma) + \varphi_2\mathrm{FDI}_{it} * \mathrm{I}(\mathrm{GTI}_{it} > \gamma) + \varphi_3\mathrm{Control}_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (7)$$

Here $GTAX_{it}$t and GTI_{it} serve as threshold variables, γ denotes the threshold value, and FDI_{it} is the explanatory variable. I represents the indicator function. Extensions to multiple thresholds are possible but not examined here.

3.2. Variable

3.2.1. Explained variable

The explained variable is LCDT. According to Li et al. [54], this study measures LCDT using the tourism carbon intensity index, calculated as the ratio of total tourism revenue to tourism-related carbon emissions, that is,

Tourism carbon intensity = Total tourism revenue/Tourism carbon emissions.

This indicator provides a simple indication of the environmental costs for the economic benefits generated by the tourism industry.

3.2.2. Explanatory variable

FDI: FDI data are taken from the China Statistical Yearbook and provincial yearbooks. To maintain consistency, values will be converted to RMB using a year-to-year USD to RMB exchange rate average [55, 56].

3.2.3. Moderating and threshold variables

GTAX: GTAX is defined as the ratio of environment-related tax revenues to GDP [57]. Environment-related tax revenue: energy tax revenue, vehicle tax revenue, pollution emissions tax, and resource utilization tax [58].

GTI: GTI is obtained by the sum of green invention patents and green utility model patents, according to Zeng et al. [44]. A log transformation has been applied to the model.

GTI = ln (Green invention patents + Green utility model patents + 1)

3.2.4. Control variables

Social Consumption Level (SC): SC stands for the sum total of the ability of the residents to purchase goods and services. It represents how important it is for a region's economy to have consumption [59]. Following Liu et al. [60], we measure it as the proportion of total retail sales of consumer goods to regional GDP.

Fiscal Expenditure (FE): FE stands for the government's capacity to regulate the economy and the environment. Fiscal resources being sufficient will make it possible for the government to support GTI and facilitate low-carbon development [61]. Following Zhou et al. [62], it is measured as the ratio of local fiscal expenditure to regional GDP.

Environmental Regulation (ER): ER shows the degree of regulation for environmentally harmful acts. Following Yan et al. [63], we measure it by the Environmental Performance Index.

Trade Openness (OPEN): OPEN is seen as an important element affecting FDI inflows, and it is linked with the level of economic development [64]. Following Bleaney and Tian [65], it is defined as the ratio of total imports and exports to regional GDP.

3.3. Data

On data availability, this study forms a panel dataset containing 30 provinces on the Chinese mainland (except for Tibet, Hong Kong, Macau, and Taiwan) from 2007 to 2022. Variable definitions and data sources are given in Table A1 of the appendix.

All variables do a unit root test first. A nonstationary series is made stationary through 1st order differencing. Post-transformation results show that all variables are stationary. It uses the variance inflation factor to check multicollinearity. There is no severe collinearity problem. The relevant results are presented in Tables A2–A3 of the appendix. All variables are winsorized at 1% to reduce the influence of outliers. Stata 18 did the analysis.

4. Empirical Results and Discussion

4.1. Fixed effects model

This study estimates models (1)–(5) and tests H1, H2, H3, H5, and H6 with the help of two-way fixed effects panel models. Table 1 presents the regression results.

From the estimation results of models (1), (2), and (3) in Table 1, we can see that FDI, GTAX, and GTI are all positively and significantly affecting LCDT. It can be seen from model (1) that the coefficient of FDI is positive and significant at 1%, which means that FDI has a significant effect on LCDT. In model 2, we can find out that the interaction terms between FDI and GTAX are positive and significant, which means that the high level of GTAX will strengthen the positive impact of FDI on LCDT.

Table 1
The regression results

LCDT	(1)	(2)	(3)	(4)	(5)
FDI	0.3320***			0.5576***	–0.2326*
	(0.0580)			(0.0531)	(0.1398)
GTAX		0.4829***		2.1742***	
		(0.0403)		(0.1394)	
GTI			0.7050***		0.5686***
			(0.0332)		(0.0510)
FDI*GTAX				–0.3604***	
				(0.0281)	
FDI*GTI					0.0429***
					(0.0148)
SC	0.4498***	0.2325***	0.0526	0.0289	0.0102
	(0.0953)	(0.0884)	(0.0723)	(0.0762)	(0.0721)
FE	0.0389	0.1439	–0.2849***	0.0237	–0.2721***
	(0.0999)	(0.0890)	(0.0747)	(0.0765)	(0.0748)

(*Continued*)

Table 1
(*Continued*)

LCDT	(1)	(2)	(3)	(4)	(5)
ER	0.5468***	0.3670***	0.0928***	0.2800***	0.1373***
	(0.0441)	(0.0391)	(0.0357)	(0.0366)	(0.0373)
OPEN	–0.3704	2.3065***	1.186149***	1.4790***	1.4874***
	(0.3239)	(0.3749)	(0.2494)	(0.3218)	(0.2644)
Cons	–5.7364***	–4.41417 ***	–5.2422***	–4.4366***	–4.8066***
	(0.5232)	(0.4447)	(0.3610)	(0.4039)	(0.4829)
Year-fixed effect	√	√	√	√	√
Province-fixed effect	√	√	√	√	√
N	480	480	480	480	480
R square	0.3531	0.4744	0.6541	0.6284	0.6700

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

From the result, we can see that it can make companies choose clean technology and thus improve the environmental benefits brought by FDI. We can see from model (3) that the interaction term between FDI and GTI is positive and significant, which means GTI improves the impact of FDI on LCDT. GTI can be used to prove that FDI has a positive environmental effect on the tourism industry, and it is conducive to the absorption and dissemination of technology in the tourism industry. The coefficients are 0.3320, 0.4829, and 0.7050, which are all statistically significant at the 1% level. This shows that these results provided a lot of empirical evidence that these factors did affect LCDT and also matched the conclusion made by Trstenjak et al. [66] and Jo et al. [67]. Thus, hypotheses 1, 2, and 5 were supported by the evidence.

From the estimation result of model (4), we can see that there are obviously interactions between FDI and GTAX. The interaction term FDI*GTAX coefficient is −0.3604, which is significant at the 1% level and means that GTAX negatively interacts with FDI on LCDT. This finding goes against the theoretical prediction in hypothesis 3, which claims that in some circumstances, GTAX will cut down the positive influence of FDI on LCDT. There are many possible causes for this.

First, GTAX may raise a firm's regulatory compliance and operating costs, thereby reducing the environmental spillovers from FDI. Regions with high GTAX intensity have significant environmental levies on businesses, like eco-taxes and carbon emissions charges, which raise business costs substantially [68]. This effect is most prominent in the tourism sector, as many FDI projects are heavy in capital investment for infrastructure building and resource usage. In GTAX regimes with high stringency, financial constraints could crowd out investment in green technology and thus undermine the positive externalities of FDI [38].

Second, changes in the degree of GTAX among the provinces would make the foreign investment companies perform spatial tax optimization; that is, they will move to the provinces where their burden is relatively less, thereby contributing to regional disparities in the low-carbon effects of FDI [69]. Given the variance in GTAX enforcement at the local level, some foreign firms may use a "race-to-the-bottom" strategy to minimize compliance costs and invest in areas with weaker environmental fiscal regimes [70].

Third, without complementary incentives, GTAX can restrict FDI in green investment. The current policies are mainly about punishment, but supporting incentives such as fiscal subsidies or green credit aren't developed enough for the kind of long-term, uncertain investment that tourism can be. Under high tax pressure and poor incentive systems, firms may be more cautious with their investments, thus limiting their contributions to low-carbon transformation [71, 72].

Model (5) results show that FDI and GTI interact significantly. The interaction term FDI*GTI coefficient value is 0.0429 and is statistically significant at the 1% level, which indicates that GTI moderately promotes the effect of FDI on LCDT. This result supports the results of Wang et al. [50] and verifies hypothesis 6.

4.2. Threshold regression

To explore any nonlinear moderation, the bootstrap threshold method and the Wald test are done on (6) and (7). The results are presented in Figure 2 and Table 2. Figures 2 and 3 show obvious changes in the coefficients at the low (L), medium (M), and high (H) levels of the moderator, reflecting nonlinear effects. Table 2 also confirms that model (6) has a single threshold and model (7) has a double threshold. Therefore, threshold regression is carried out, the estimation results of which can be seen in Table 3.

Figure 2 displays the estimated marginal effects of FDI (X) on LCDT (Y) at various levels of GTAX (moderator, D). The X-axis represents the moderator GTAX, which goes from low (L) to high (H), and the Y-axis represents the marginal effect of FDI (X) on LCDT (Y), which reflects the way that the FDI changes affect LCDT at different GTAX levels. The shaded area is the 95% confidence interval, and the histogram at the bottom is the distribution of GTAX. The results show that there is a single-threshold nonlinear effect, where the marginal effect of FDI on LCDT decreases with an increase in GTAX, indicating that the higher the green tax level, the lower the positive impact of FDI on LCDT.

Figure 3 shows the estimated marginal effects of FDI (X) on LCDT (Y) for different levels of GTI (moderator, D). The X-axis shows GTI, ranging from low level (L) to high level (H); the Y-axis indicates the marginal impact of FDI (X) on LCDT (Y). The shaded area is the 95% confidence interval, and the histogram shows the distribution of GTI. The results suggest a double-threshold nonlinear pattern, indicating that the moderating role of GTI varies at two threshold points. When GTI is less than the threshold, FDI has little impact on LCDT. As GTI reaches higher levels, FDI's positive influence on the low-carbon transition becomes more significant.

Figure 2
Nonlinear impacts revealed in model 6

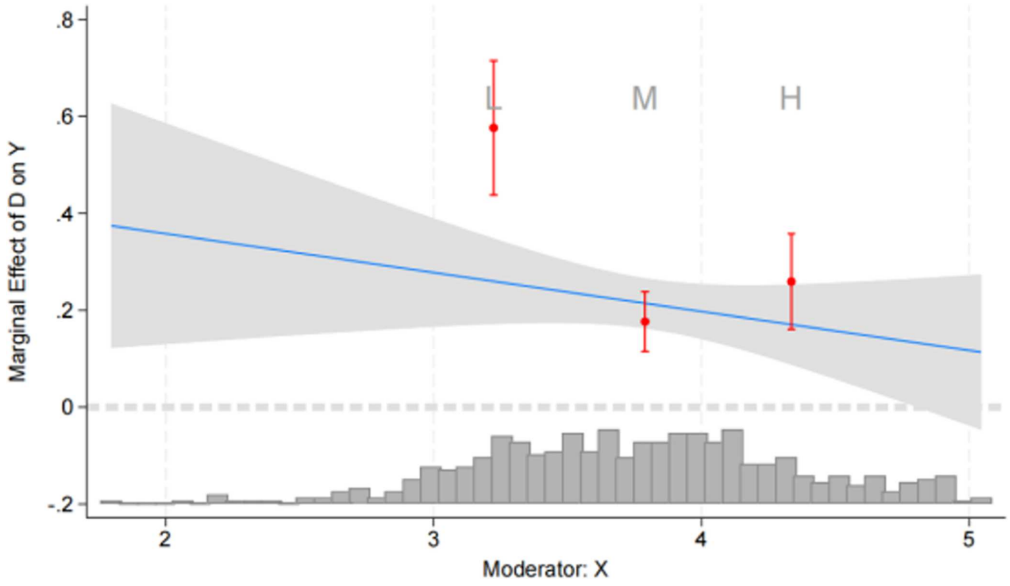


Table 2
Threshold effects results

Model	Variables	Type	Values	*p*-values	95% conf. interval
(6)	GTAX	Single	1.3341	0.0000	[1.2632, 1.3739]
		Double	/	/	/
(7)	GTI	Single	7.1944	0.0000	[7.0757, 7.2729]
		Double	8.7562	0.0133	[8.6808,8.7915]

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Figure 3
Nonlinear impacts revealed in model 7

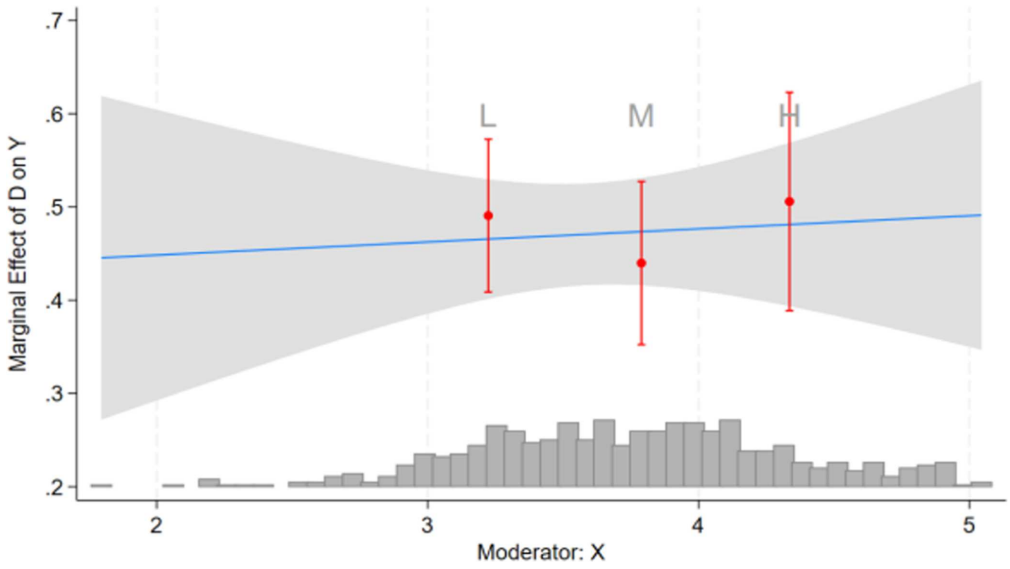


Table 3
Threshold effects regression results for each variable

Model	(6)		(7)	
FDI*LCDT(GTAX ≤ 1.3341)	0.1047*	0.059		
FDI*LCDT(GTAX > 1.3341)	0.3864***	0.000		
FDI*LCDT(GTI ≤ 7.1944)			–0.1505**	0.02
FDI*LCDT(7.1944 < GTI ≤ 8.7562)			0.1480***	0.004
FDI*LCDT(GTI > 8.7562)			0.3845***	0.000
SC	0.2637***	0.002	0.1933**	0.019
FE	0.0371	0.674	–0.0903	0.291
ER	0.4232***	0.000	0.3593***	0.000
OPEN	–0.2456	0.392	–0.0921	0.739
Year-fixed effect	√	√	√	√
Province-fixed effect	√	√	√	√

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

4.2.1. Threshold effects of GTAX

The estimation results of model (6) show that there is a significant one-threshold effect for the moderating effect of GTAX on the relationship between FDI and LCDT. The estimated threshold value of GTAX is 1.3341 with a narrow confidence interval, and it is significant at 1% level, indicating the robustness of the threshold. Compared with the regime-wise coefficient estimates, a large amount of heterogeneity can be seen. When GTAX < 1.3341, the marginal effect of FDI on LCDT is low (coefficient = 0.1047). Contrariwise, once GTAX > 1.3341, the coefficient skyrockets to 0.3864. This implies that a high level of GTAX significantly enhances the positive spillover effect of FDI on LCDT as it may raise the environmental incentive and the credibility of institutions.

When GTAX is under the specified threshold value (1.3341), the positive impact of FDI on LCDT is not obvious, and the influence is only slightly significant. This can be due to various reasons. First, inadequate environmental regulatory pressure when GTAX is low results in firms not investing enough in emission reduction, and thus, foreign firms keep carbon-intensive technologies. Second, "pollution haven" effect persists; some FDI is driven by cost minimization rather than technology upgrade and therefore makes a little contribution to decarbonization. Third, low levels of GTAX will prevent foreign companies from participating in high-cost, low-carbon innovation or cooperating with local enterprises, which will lead to the green technology spillover effect being constrained.

On the contrary, when GTAX > 1.3341, the positive effect of FDI on LCDT is significantly magnified. First, higher environmental costs activate the innovation compensation effect. FDI enterprises use advanced technologies from home countries to reduce compliance costs [73]. Second, GTAX levels that are high act as convincing market indicators, drawing FDI oriented toward green that considers low-carbon capabilities as something advantageous, particularly in new areas like eco-tourism and carbon-neutral travel [74]. Third, stricter environmental tax regimes facilitate local supply chain upgrading, compelling FDI to align with evolving sustainability standards and fostering a virtuous cycle of technological spillovers and industrial transformation. Thus, H4 is validated.

4.2.2. Threshold effects of GTI

In order to achieve an overall understanding, this research will adopt a progressively explanatory mixed-methods approach, allowing for the triangulation of findings. This design helps to explain that the relationship between digital banking and sustainability is quite complex, as well as the constraints that result from using only one of them.

The estimation results of model (7) reveal solid proof for the occurrence of a double-threshold effect in the moderating function of GTI to the FDI–LCDT relationship. When GTI is below 7.1944, FDI negatively affects LCDT. This implies that in contexts without strong GTI capacity, FDI might bring about environmentally bad effects, like the transfer of carbon-heavy production or pollution-heavy operations. GTI exceeds the first threshold but remains under the second (7.1944–8.7562); thus, the effect of FDI is positive, meaning a moderate level of GTI boosts absorptive capacity and enables more effective use of green technologies introduced by foreign firms. GTI > 8.7562, when GTI surpasses the second threshold, the positive impact of FDI gets intensified. It shows a better combination of domestic green abilities and FDI, promoting the spreading of low-carbon technologies, sustainable management, and green supply chain in tourism.

The findings indicate that at low levels of GTI, the limited technological capacity and weak environmental governance in host regions tend to attract FDI characterized by pollution-intensive and energy-consuming activities, thereby exerting a detrimental impact on LCDT [37]. As GTI reaches a moderate level, improvements in the host country's absorptive capacity and regulatory enforcement enable foreign firms to partially adopt cleaner technologies and adapt to environmental standards, thus shifting FDI toward a more supportive role in the green transition [75]. At high levels of GTI, a mature domestic green innovation system and stringent regulatory environment compel foreign-invested enterprises to comply with higher environmental benchmarks. Simultaneously, enhanced local capabilities in technology absorption, imitation, and re-innovation facilitate deeper FDI-technology integration, significantly amplifying the positive contribution of FDI to LCDT. These dynamics are consistent with the findings of Fang et al. [11] and Ngoc et al. [76]. Thus, H7 is validated.

4.3. Heterogeneity analysis

4.3.1. Heterogeneity analysis on different economic development levels

To explore the impact of economic development heterogeneity on the FDI–LCDT nexus, this study follows Li et al. [54] and calculates the average real per capita GDP for each province from 2007 to 2022. Based on the median value, provinces are classified into high and low-development groups. Separate regressions are then performed for each subgroup. The results are reported in Table 4.

In high economic development regions, the moderating role of GTI in the relationship between FDI and LCDT is statistically insignificant. This heterogeneity reflects a possible attenuation of the FDI–GTI interaction mechanism. First, these regions often exhibit mature green innovation systems, robust technological foundations, and comprehensive policy support, which may result in diminishing marginal contributions of new FDI to technological upgrading—an "innovation saturation" effect [77]. Second, FDI in such areas is predominantly market-seeking, driven by consumption and expansion motives rather than technological spillovers, thus limiting its capacity to catalyze green transitions [78]. Third, local governments often use proactive, well-institutionalized policies for low-carbon development, where fiscal and policy instruments may overshadow or substitute the FDI–GTI interaction [79].

4.3.2. Heterogeneity analysis on different geographic locations

Given that there are large differences in economic development levels among different regions in China, industrial structures, and the implementation of green development policies, there are noticeable differences in the distribution and levels of GTAX burdens and GTI across provinces [11]. In order to see if such differences in space affect the role of FDI in driving LCDT, the paper follows Gao et al. [80] by separating the sample into three large geographic regions: eastern, central, and western China. Panel threshold regressions are then run on a separate basis for each of the sub-regions. The result is shown in Table 5.

In the eastern area, the interaction FDI*GTAX is significantly negative (−0.3399, $p < 0.01$), indicating that the stricter

Table 4
Heterogeneity analysis across different economic development levels

Variables	High economic development		Low economic development	
FDI	0.8581***	–0.0956	0.3333***	–0.5836***
	(0.0958)	(0.3942)	(0.0767)	(0.2179)
GTAX	2.3407***		2.2889***	
	(0.1847)		(0.2160)	
GTI		0.6605***		0.5106***
		(0.1512)		(0.0647)
FDI*GTAX	–0.4103***		–0.2854***	
	(0.0373)		(0.0538)	
FDI*GTI		0.0144		0.0907***
		(0.0409)		(0.0243)
Controls	ok	ok	ok	ok
Year-fixed effect	√	√	√	√
Province-fixed effect	√	√	√	√

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 5
Heterogeneity analysis across eastern, central, and western China

Variables	Eastern		Central		Western	
FDI	0.5770***	–0.9556***	0.9459***	3.0060***	0.2568***	–0.3375
	(0.1357)	(0.2933)	(0.1170)	(0.5876)	(0.0710)	(0.2414)
GTAX	1.9924***		2.4775***		2.1448***	
	(0.2661)		(0.1286)		(0.2000)	
GTI		0.3890***		1.9088***		0.4512***
		(0.1308)		(0.2204)		(0.0680)
FDI*GTAX	–0.3399***		–0.4555***		–0.2945***	
	(0.0516)		(0.1024)		(0.0547)	
FDI*GTI		0.0911***		–0.3226***		0.0614**
		(0.0311)		(0.0623)		(0.0286)
Controls	ok	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√	√
Province-fixed effect	√	√	√	√	√	√

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

GTAX weakens the positive effect of FDI on LCDT. On the other hand, the interaction FDI*GTI is significantly positive (0.0911, $p < 0.01$), which means that the advancement of GTI enhances the environmental spillover effect of FDI in this region.

In the central region, FDI*GTAX(−0.4555) and FDI*GTI(−0.3226) are both statistically significant at 1% with a negative coefficient. This means that GTAX and GTI do not currently serve as facilitators for FDI-driven decarbonization of the tourism industry. Instead, it seems that it has a countervailing effect due to the constraints of institutions, absorptive capacity, or misaligned policies.

In the west region, FDI*GTAX coefficient −0.2945, with the same negative sign, which shows that GTAX suppresses FDI's environmental performance. However, the interaction FDI*GTI is positive and significant at the 5% level (0.0614, $p < 0.05$), meaning that the GTI in this area seems to have a certain catalytic effect on the low-carbon benefits of foreign investment, but only to a small extent.

Heterogeneity analysis shows that there are different regional differences in FDI–GTI synergies on LCDT. In the central region, the negative interaction suggests a decoupling, which is probably because of the underdeveloped green technologies, limited commercialization, and low integration with tourism [81]. Moreover, FDI here tends to go into traditional or resource-heavy sectors [82], making it hard for the area to turn green and putting more stress on the environment. Contrary to this is the east that has matured its innovation systems and strong absorptive capacity, which enable efficient integration of FDI–GTI and promote LCDT. In the western region, although economic development is weaker, targeted policies have attracted FDI into ecological and sustainable tourism projects, enhancing the FDI–GTI synergy. Overall, the effectiveness of this interaction depends on institutional quality, innovation maturity, and the alignment between foreign capital and local green strategies.

4.4. Robustness test

4.4.1. Dynamic adjustment test

Reciprocal causality between GTAX, GTI, and LCDT is present, which results in endogeneity issues that may affect the accuracy of the parameter estimates. To deal with this problem, this study follows Wang [83] to include one-period lagged values of the main explanatory variables. The outcomes in Table 6 are generally consistent with the baseline results, which supports the robustness of the empirical findings.

4.4.2. Extreme value trimming test

To address potential biases arising from extreme observations, this study follows Li et al. [54] and excludes the top and bottom 1%, 5%, and 10% of values for GTAX and GTI. This yields sub-samples of 29, 28, and 27 provinces, respectively. Threshold regressions are then re-estimated using these trimmed samples. The empirical results in Table 7 closely align with the baseline findings, thereby confirming the robustness of the model.

Table 6
Threshold regression results using lagged explanatory variables

	(6)	(7)
FDI*LCDT(GTAX ≤ γ1)	0.1456**	
	(0.0576)	
FDI*LCDT(GTAX > γ2)	0.3897***	
	(0.0530)	
FDI*LCDT(GTI ≤ γ1)		–0.0568
		(0.0655)
FDI*LCDT(γ1 < GTI ≤ γ2)		0.2139***
		(0.0541)
FDI*LCDT(GTI > γ2)		0.4115***
		(0.0511)
Controls	ok	ok
Year-fixed effect	√	√
Province-fixed effect	√	√

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 7
Extreme value trimming test results

	1%		5%		10%	
	(6)	(7)	(6)	(7)	(6)	(7)
FDI*LCDT(GTAX ≤ γ1)	0.1394**		0.1257*		0.1302*	
	(0.0655)		(0.0686)		(0.0734)	
FDI*LCDT(GTAX > γ2)	0.4190***		0.4104***		0.4143***	
	(0.0601)		(0.0630)		(0.0672)	
FDI*LCDT(GTI ≤ γ1)		–0.1939**		–0.198**		–0.221***
		(0.0754)		(0.0778)		(0.0818)

(*Continued*)

Table 7
(*Continued*)

	1%		5%		10%	
FDI*LCDT($\gamma 1 <$ GTI $\leq \gamma 1$)		0.1382**		0.1447**		0.1213*
		(0.0595)		(0.0621)		(0.0664)
FDI*LCDT(GTI > $\gamma 1$)		0.3484***		0.3643***		0.3473***
		(0.0560)		(0.0585)		(0.0619)
Controls	ok	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√	√
Province-fixed effect	√	√	√	√	√	√

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 8
Threshold effects with energy intensity as an additional control

	(6)	(7)
FDI*LCDT(GTAX $\leq \gamma 1$)	0.1237**	
	(0.0487)	
FDI*LCDT(GTAX > $\gamma 2$)	0.2901***	
	(0.0461)	
FDI*LCDT(GTI $\leq \gamma 1$)		–0.0484
		(0.0588)
FDI*LCDT($\gamma 1 <$ GTI $\leq \gamma 2$)		0.1640***
		(0.0456)
FDI*LCDT(GTI > $\gamma 2$)		0.3083***
		(0.0450)
Controls	ok	ok
Year-fixed effect	√	√
Province-fixed effect	√	√

Note: *$p < 0.1$, **$p < 0.05$, *** $p < 0.01$.

4.4.3. Additional control variables

To further test robustness, energy intensity (EI) was added as a control in the threshold regression. As presented in Table 8, the inclusion of EI yields consistent results with the baseline estimates, further validating the robustness of the empirical findings.

5. Conclusion

5.1. Key findings

Based on the panel data from 30 Chinese provinces for the period of 2007–2022, this study uses the panel threshold model with two-way fixed effects to empirically test the impact of FDI on LCDT with the emphasis on the moderating roles of GTAX and GTI. First, FDI, GTAX, and GTI all significantly promote LCDT. Second, GTI positively moderates the FDI–LCDT relationship, while GTAX negatively moderates the FDI–LCDT relationship. Third, the moderating effects show regional differences. These results show that FDI's environmental outcomes depend on the situation, and it is very important to make fiscal and innovation policies match the plans for regional growth.

5.2. Discussion

The empirical findings are mostly in line with the hypotheses that were put forward, but there are a few results that don't conform to what was anticipated. This study also lookedinvestigates for the reasons behindof the matter as well as the theory.

5.2.1. Main effects perspective

The empirical results of the study show that FDI, GTAX, and GTI all significantly promote LCDT. H1, H2, and H5 have been proven by empirical facts, and H6 cannot be verified. This conclusion is consistent with the findings of other studies [55, 72]. Moreover, this study empirically shows that China's policy-oriented approach can promote the market-oriented allocation of green factors, improve the resource structure, and achieve high-quality tourism development. Specifically, GTAX, as an environmental regulation, has played an important role in guiding the fulfillment of corporate environmental responsibilities and has effectively contributed to the achievement of the goals of achieving cleaner production and reducing emissions [57]. Meanwhile, GTI has strengthened the internal momentum for LCDT in terms of energy efficiency and promotion of the application and commercialization of green products and services [84].

5.2.2. Moderating effects perspective

The empirical results show that GTAX has a negative moderating effect on the relationship between FDI and LCDT, and GTI has a significant positive moderating effect. H4 and 7 are validated. This result indicates that under continuously growing environmental tax pressure, the increased burden of enterprise costs can lead to resistance or passive responses to GTAX and discourage green investment behavior. On the other hand, GTI can enhance energy efficiency and reduce the marginal cost of environmental management, which can offset some cost constraints and thus strengthen the positive impact of FDI on LCDT.

5.2.3. Heterogeneity perspective

Based on two aspects, namely, the level of economic development and geographical location, the empirical results show that the effect of FDI on LCDT shows obvious heterogeneity.

Economically developed areas do not have a significant moderating effect of GTI on FDI–LCDT. Maybe it is because of the existing green infrastructures and formed low-carbon mechanism, which enables foreign enterprises to manage the tourism green transformation without considering local innovation, and less interaction between GTI and FDI results in few practical technology outcomes.

As for the geographical location, GTI negatively moderates the FDI–LCDT relationship in central China and positively in eastern and western regions, indicating differences in green technology absorption, FDI efficiency, and institutional environment. In the central areas, weak green industries and mismatches with technology can disrupt the FDI–GTI synergy, but the strong technological foundation and market mechanism in the eastern area facilitate interaction, and the western area enjoys policy support and incentives for green investment. Thus, region-specific strategies must be developed, which include improving the technological capacity and institutional support of central regions and improving cross-regional cooperation.

6. Theoretical Contributions and Policy Implications

6.1. Theoretical contributions

The study contributes some important theoretical insights and provides a new understanding of how FDI encourages LCDT and improves the scientific understanding of the environmental effect of FDI under an institutional and technological context.

First, this research transcends the traditional constraints of FDI's environmental impact theories that were mainly centered around the manufacturing industry, for the first time integrating the "pollution halo" and "pollution haven" theories into the tourism sector, a part of the service sector. The development of a comprehensive FDI–GTAX–GTI has been presented as an approach, which displays the pathway through which the FDI would trigger LCDT via the processes of technology spillovers, upgrading managerial performance or following the environmental standards globally. It links the industrial and service-sector perspectives and demonstrates that the environmental impacts of FDI are neither dependent solely on the size of investment nor a simple additive effect of the synergetic effects between capital and fiscal incentives with technology. It makes up for deficiencies in the traditional theories and develops from the pollution halo to a multidimensionally constructed institutional and technical environment.

Second, this research introduces both moderating and threshold effect models that exceed the traditional linearity assumptions of environmental economics and empirically illustrates nonlinear, context-dependent interactions among FDI, GTAX, and GTI. Utilizing a panel threshold model, the latter empirically identifies significant nonlinear effects: one threshold for GTAX (1.3341) and two for GTI (7.1944, 8.7562). These findings indicate that FDI green effects rely on local institutional and technical conditions, supporting the "optimal environmental regulation intensity" theory and improving the conditional applicability of the pollution haven hypothesis. Validating when and where FDI results in green outcomes makes theoretical precision better and creates a way that can be copied to look at FDI and the environment in other parts of business areas.

Third, this study finds that there are large regional differences in the synergetic effects of FDI and GTI: an enhancing effect in the eastern region, a negative effect in the central region, and a complementary effect in the western region. The jumbled-up answers have people guessing if there's a clear way for companies to get fresh ideas when they are inside bigger businesses from other places, saying we need to see where it happens and by what rules. It proposes an institutional quality–innovation maturity–FDI structure, which suggests that the environmental effectiveness of FDI is conditional upon the environment of local governance, innovation capacity, and absorptive capacity. This idea brings about a more adaptive theory, one that integrates regional differences into the concept of sustainable tourism and the green transformation.

The sum of these efforts contributes to a better idea of how FDI, along with GTAX and GTI, can lead to LCDT, by adding to FDI theories the dimensions of service economy-based societies.

6.2. Policy implications

6.2.1. From the perspective of FDI promoting LCDT

To strengthen FDI's role in LCDT, policymakers should stress that investments should be environmentally and technologically good, getting projects that use new green tech, save energy, and have friendly-to-the-environment buildings. A transition is from a focus on quantity to one on quality of FDI, such that foreign capital contributes to both growth and carbon reduction.

Additionally, regional policy differences are needed to maximize the green spillover effects of FDI. In the eastern provinces, where innovation capacity and institutional maturity are strong, policy emphasis should be on strengthening technology synergy between foreign and domestic firms to consolidate innovation-driven LCDT. Central regions need to enforce environmental regulations and monitor them more strictly to avoid "pollution havens," and western provinces should take proactive steps like offering green subsidies, tax cuts, and land-use benefits to attract sustainable FDI and promote regional transformation.

Furthermore, policy frameworks should also try to improve the design and execution of GTAX by introducing differential and performance-based tax benefits that reward lower carbon production and penalize higher carbon emissions. Both these kinds of mechanisms push foreign investors to utilize greener tech and align local tax policy with the worldwide sustainable goal.

At the same time, the government can promote regional innovation collaboration and technology transfer through a platform that connects FDI companies, research organizations, and local companies. Leverage FDI to import and localize low-carbon technologies that could produce positive spillover effects, enhance local innovation, and expedite a low-carbon tourism transition. Establishing an open, consistent policy environment combining green finance, taxation, and supporting innovation to further guarantee the sustainability of the effect of FDI on LCDT.

6.2.2. From the perspective of the moderating role of GTAX

Due to the persistent negative interaction of GTAX with FDI toward LCDT, it can therefore be stated that the existence of the GTAX system in China is a negative cost to China and not a green incentive, indicating no regional guidance. Therefore, this paper puts forward the following suggestions:

1) Cost buffering and dynamic compensation mechanisms. Provide temporary tax exemptions for key green tourism investments such as low-carbon transportation and zero-carbon

hotels to ease the compliance costs. A "green tax-to-subsidy" mechanism should be established, whereby some of the firms' environmental taxes are redirected toward their own green technology upgrades or carbon offsets, lowering short-term costs and improving long- term innovation incentives and transforming GTAX into a strategic reinvestment tool.

2) Establish a national baseline for GTAX. The existing GTAX structure of China is without a common baseline, leading to uneven execution and the possibility of interregional tax competition. To establish a national GTAX benchmark that provides some provincial flexibility is to achieve both fairness and adaptability, and "green investment tax credits" in fragile or underdeveloped areas could encourage FDI into low-carbon projects through deductions for verifiable green investments. This policy will help to move capital into regions that have a higher environmental worth, while also balancing economic and ecological objectives.
3) Strengthen the green incentives policy mix. Policies can be interest subsidies for green credit of FDI-related low-carbon tourism, tax credit for using green technology, and corporate income deduction for certified low-carbon investment to promote technological transformation. Additionally, a pilot green transformation insurance fund, co-funded by governments and financial institutions, can share the risk of adoption and strengthen investors' confidence in sustainable development.

On the whole, these measures would turn GTAX into a dynamic administration mechanism as opposed to a static fiscal device, for the environmental taxes should match up with the development of technology and regional sustainability. Doing so would turn GTAX from a temporary restraint to a long-run driver of green competitiveness and low-carbon transition in the Chinese tourism industry.

6.2.3. From the perspective of heterogeneity

In terms of economic development level, it is recommended to adopt a gradual "technology first, then tax" policy approach to increase the positive effect of FDI on LCDT. First, efforts can be made to support GTI, including creating industry–academia–research collaboration platforms and providing incentives for the transfer of green patents to improve its effectiveness in local applications. Second, drawing on the experience of Guo et al. [85] in the logistics sector, phased and regionally differentiated green incentive policies should be promoted to ensure synergy between environmental regulation and the supply of technological capabilities. Finally, in conjunction with global research on carbon pricing and referencing the conclusion of Ahmad et al. [86], a moderate increase in carbon tax can significantly reduce carbon emissions. A gradual increase in GTAX burden should be implemented to facilitate LCDT driven by FDI, GTI, and GTAX.

In terms of regional heterogeneity, it is recommended that the central region advance along two dimensions simultaneously. First, efforts should be made to strengthen the capacity for green technology collaboration and transformation. Drawing on the coordinated industry–university–research mechanisms proposed by Ketchoua et al. [77], FDI enterprises should be encouraged to jointly establish green pilot projects with local universities and innovation institutions to facilitate technology demonstration and conversion. At the same time, based on Sun et al. [40], who construct a synergistic network of green innovation knowledge, policy, and personnel within the renewable energy sector, policy incentives should be designed to foster a regional "super-network" of green innovation. Second, the GTAX framework should be adjusted to better facilitate the inflow of green FDI. For instance, FDI projects introducing and localizing green technologies could receive tax deductions or phased reductions. Additionally, a portion of GTAX revenue could fund a "Green Technology Development Fund" for the central region, providing subsidies to offset firms' green transition costs.

7. Limitations and Directions for Future Research

FDI and LCDT are related to each other through certain contextual factors, which is an area of interest for further research. Specifically, we analyze only GTAX and GTI now. Future studies can add some more factors that can influence the study.

In addition, only the panel bidirectional fixed effect model is used to study the relationship between variables. In future research, it can be done by using another model (coupled coordination models, game theory, etc.).

Ethical Statement

This study does not contain any studies with human or animal subjects performed by the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

The data that support this work are available upon reasonable request to the corresponding author.

Author Contribution Statement

Jianquan Guo: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Thi Hai Hoan Pham:** Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization.

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Appendix

Table A1
Variable definitions and data sources

Variable	Symbol	Measure	Data sources
Foreign direct investment	FDI	Actual FDI inflows by province	China Trade and Economic Statistics Yearbook
Low-carbon development in the tourism sector	LCDT	The ratio of total tourism revenue to tourism-related carbon emissions	China Statistical Yearbook
Green taxation	GTAX	Environment-related tax revenue as a percentage of GDP	China Research Data Services Platform (CNRDS)
Green technological innovation	GTI	The natural logarithm of the sum of green invention patent applications and green invention patent grants, plus one	China Research Data Services Platform (CNRDS)
Social consumption level	SC	Ratio of total retail sales of consumer goods to regional GDP	China Statistical Yearbook
Fiscal expenditure	FE	Ratio of local fiscal expenditure to regional GDP	China Statistical Yearbook
Environmental regulation	ER	Environmental Performance Index (EPI)	China Statistical Yearbook
Trade openness	OPEN	Ratio of total imports and exports to regional GDP	China Statistical Yearbook

Table A2
Variance inflation factor (VIF) test

Variables	VIF	1/IVF
GTI	3.87	0.258219
FDI	3.74	0.267461
GTAX	3.32	0.300908
FE	2.48	0.403422
OPEN	1.45	0.691524
ER	1.37	0.728930
SC	1.37	0.730415
Mean VIF	2.51	

Table A3
Descriptive statistics results

Variables	Obs	Mean	SD	Min	Max
LCDT	480	1.41	1.00	0.11	4.79
FDI	480	3.07	1.69	–3.88	5.42
GTI	480	8.59	1.59	3.64	11.94
GTAX	480	1.94	1.91	0.07	11.73
SC	480	3.78	0.58	1.80	5.04
FE	480	2.46	1.08	0.97	7.58
ER	480	8.12	2.61	4.02	16.19
OPEN	480	0.29	0.32	0.01	1.67