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Original Research Article

Exploring the Nonlinear Relationship between Green Finance and Urban Low-Carbon Transformation

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Abstract: Green finance has become a critical financial mechanism for advancing urban low-carbon transformation, yet its environmental effects remain theoretically contested between the "green promotion" hypothesis and the "green paradox." Existing literature largely concentrates on industrial and energy-sector transitions, overlooking the urban dimension. Drawing on panel data for 261 Chinese cities from 2006 to 2023, this study employs a panel threshold model with two-way fixed effects to examine the nonlinear relationship between green finance and urban low-carbon transformation, with particular attention to the roles of industrial structure upgrading and government attention. The results reveal that: (1) green finance, industrial structure upgrading, and government attention all significantly facilitate urban low-carbon transformation; (2) both industrial structure upgrading and government attention exert negative moderating effects on the contribution of green finance to urban low-carbon transformation; and (3) these moderating effects display pronounced heterogeneity across cities. The findings extend the theoretical understanding of the environmental effects of green finance within the urban context and uncover the multidimensional drivers of urban low-carbon transition. In practice, this study provides evidence-based insights for improving China's green financial system, refining industrial upgrading pathways, and enhancing government governance mechanisms, thereby supporting high-quality urban development amid global green transition efforts.

Keywords: Green Finance, Urban Low-Carbon Transformation, Industrial Structure Upgrading, Government Attention, Nonlinear Relationship.

1. INTRODUCTION

Over the past decade, the environmental and economic risks associated with global climate change have intensified, prompting the international community to accelerate the transition toward low-carbon and sustainable development models. Countries worldwide have formulated carbon-neutrality visions and climate action roadmaps to achieve deep decarbonization in high-emission sectors such as energy, transportation, and construction. Meanwhile, green investment and sustainable finance have gradually become crucial pillars of global climate governance, as financial systems play an increasingly important role in climate-risk identification, green project financing, and the diffusion of low-carbon technologies (Fu *et al*., 2024). Policies such as the European Union's "Green Deal," the United States' "Clean Energy Act," and Japan's "Green Growth Strategy" collectively indicate a global shift from traditional high-carbon growth paths toward innovation-driven green development (Steven *et al*., 2026). In this transformation, cities—major hubs of carbon emissions and resource consumption—have emerged as strategic frontiers and policy testbeds for global low-carbon transition.

Against this backdrop, China has actively integrated green and low-carbon development into its national strategic framework, establishing a distinctive green development model through green finance–driven energy restructuring and related measures (Wang, 2025). In recent years, the government has successively introduced policy documents such as the Overall Plan for Green Finance Reform and Innovation Pilot Zones and the Guiding Opinions on Promoting Urban Green and Low-Carbon Transformation, which guide financial resources toward energy conservation, emission reduction, ecological restoration, and clean production (Xu *et al*., 2024). Green finance has thus become an essential instrument for advancing urban green development and achieving China's "dual-carbon" goals (Du *et al*., 2025). It not only provides stable financial support for urban low-carbon transition but also offers institutional guarantees for regional coordination and ecological governance (Yao *et al*., 2025).

Existing studies generally argue that green finance promotes investment in green industries by optimizing capital allocation, refining risk pricing, and enhancing environmental information disclosure, thereby improving urban carbon-emission efficiency and resource allocation performance (Hu *et al*., 2023). Meanwhile, the development of green credit, green bonds, and green funds fosters technological innovation and industrial restructuring, further supporting urban low-carbon transformation (Xie *et al*., 2023). At the urban level, green finance contributes to a virtuous "finance–industry–environment" cycle through the reallocation of financial resources, the diffusion of green innovation, and strengthened environmental governance incentives (Mirza *et al*., 2025). Therefore, systematically assessing the role of green finance in promoting low-carbon transformation from an urban perspective is crucial for achieving both regional emission reduction and high-quality economic growth.

Moreover, the effectiveness of urban low-carbon transformation is not solely determined by financial factors; it is also jointly influenced by industrial structure upgrading and government attention. On the one hand, industrial structure upgrading reduces the proportion of energy-intensive industries while expanding the share of services and high-technology sectors, thereby improving energy efficiency and strengthening the transmission effect of green finance (Mohammed *et al*., 2025). On the other hand, government attention amplifies the impact of green finance at the macro level through environmental regulatory policies, strengthened public supervision of green issues, and enhanced fiscal incentive mechanisms (Li *et al*., 2025). Therefore, examining how green finance functions under the dual moderating effects of industrial structure upgrading and government attention is not only theoretically valuable but also of great practical significance for achieving China's "dual-carbon" goals and promoting sustainable urban development.

In summary, this study incorporates industrial structure upgrading and government attention as moderating variables to explore the relationship between green finance and urban low-carbon transformation. The research addresses the following questions:

1) Does green finance promote urban low-carbon transformation?
2) Do industrial structure upgrading and government attention contribute to urban low-carbon transformation?
3) How do industrial structure upgrading and government attention moderate the impact of green finance on urban low-carbon transformation?
4) Do these effects exhibit heterogeneity across regions with different geographic and developmental characteristics?

The contributions and innovations of this study are as follows:

First, this study develops a comprehensive analytical framework linking "green finance–industrial structure upgrading–government attention–low-carbon transformation," revealing how green finance influences urban low-carbon transition through resource reallocation, green innovation diffusion, and environmental governance incentives. This provides new empirical evidence for expanding the multi-level governance perspective within green finance research.

Second, by constructing an integrated analytical framework that includes green finance, industrial structure upgrading, and government attention, this study broadens the theoretical perspective of urban low-carbon transformation research. While previous literature has examined the independent effects of industrial upgrading or environmental regulation, few studies explore how these factors function as "amplifiers" within the green finance mechanism. By incorporating both industrial structure upgrading and government attention into the transmission pathway, this study separately tests their moderating effects, demonstrating that advanced industrial structures enhance the diffusion of green technologies, whereas government attention magnifies the macro-level influence of green finance through policy design, public oversight, and fiscal incentives. This reveals a novel interaction mechanism.

Third, using detailed city-level data and employing multiple-threshold models, regional heterogeneity tests, and extensive robustness checks, this study identifies significant differences in how green finance promotes low-carbon transformation across various threshold levels and stages of regional development. The findings not only confirm the nonlinear characteristics of green finance policies but also uncover substantial disparities in industrial structures and governance capacities among eastern, central, and western cities. These insights provide more actionable empirical evidence for formulating region-specific green finance policies and low-carbon transition pathways.

2. LITERATURE REVIEW AND HYPOTHESES

2.1 Green Finance and Urban Low-Carbon Transformation

As China's "dual-carbon" strategy gets deeply carried out, urban development has entered a key period for making the transition to a low-carbon model. As the major consumer of energy and source of carbon emissions, accounting for over 85% of the national total, the low-carbon level of cities is tied to the attainment of the dual-carbon goals (Liang Chen *et al*., 2024). Facing the process of rapid urbanization, green finance is an important path for urban low-carbon development by improving resource allocation, improving environmental governance and promoting the spread of green technology (Dhayal *et al*., 2025). Directing financial resources towards energy saving, emission reduction, and green industries will improve urban energy efficiency and promote the green transition of urbanization by improving the quality of the urban environment, which can make urban competitiveness and sustainable development capacity stronger (Hu *et al*., 2023).

During the transformation of urban low carbon, green finance is playing a critical role in leading the flow of funds, restructuring the industries, and promoting green technological innovation. On one hand, instruments such as green credit, green bonds, and green funds ease financing constraints for green projects, and reallocate capital from pollution-heavy and energy-intensive sectors to green industries. This redirection is supportive of clean energy, green buildings, green transport, and other parts of low carbon urban infrastructure (Ouni *et al*., 2025; Bo Zhou *et al*., 2025). On the contrary, green finance promotes enterprises to take on green innovation actively through improving risk pricing and disclosing environment information. It guides enterprises to abide by green standards and environmental regulation. And this process can improve the overall urban environmental governance and technology (Sun *et al*., 2025; Deng *et al*., 2023). Moreover, previous studies show that a well-formed green financial system can enhance the incentive of green environmental governance, improve the expected returns of green projects, speed up the spread of green technologies, and finally push forward the low-carbon transformation of urban energy systems (Q. Zhang *et al*., 2025).

Existing studies on green finance and urban low-carbon development also tend to support these views. Wang and Zhang (2025) find that green credit policies significantly boost urban energy efficiency and promote the green upgrade of energy-intensive industries. G. Based on city-level panel data. Zhang *et al*., (2024) proved that the development of green finance can significantly improve the green innovation capacity of urban, with a larger effect on eastern cities. Liu *et al*., (2021) and X. Liu and Zhang (2023) further pointed out that green finance can indirectly improve the urban carbon emission performance through the restraint on the expansion of pollution-intensive industry and promotion of technology-biased progress. Meanwhile, Mirza *et al*., (2025) stressed that cities with more developed governance systems can have the green finance perform better on its roles of directing capital and relaying policies to enable the entire transition towards low-carbon from the perspective of energy, industry and governance. Taken together, these findings show that green finance both nurtures firm-level green innovation and optimizes the allocation of crucial resources needed for urban low-carbon development, making green finance an indispensable force propelling urban low-carbon transformation.

Based on the above analysis, this study proposes the following hypothesis:
H1: Green finance promotes urban low-carbon transformation**.**

2.2 Industrial Structure Upgrading, Green Finance, and Urban Low-Carbon Transformation

Based on the role of green finance in promoting urban low-carbon transformation, industrial structure transformation and upgrading has an important function in strengthening the urban low-carbon transformation. Specifically, industrial structure upgrading that is from resource and energy intensive to high tech, service oriented and environment friendly, improves the effectiveness of green finance in driving urban low carbon transition (Gao *et al*., 2023). Green financial instruments merged with industrial upgrading policies give important capital to clean techs and make companies use eco-friendly ways to make things, this lowers how much carbon cities have and makes using energy better (Jin *et al*., 2025). Therefore, the interaction of industrial structure upgrading and green finance is an important path to achieve the dual goals of urban low-carbon transformation and economic modernization.

Industrial structure upgrading is gradually becoming an important way to promote green and low-carbon urban development (Dhayal *et al*., 2025). It seems all over the place. First, by optimizing the allocation of resources, it transforms the economic activities away from high-energy, high-emission traditional industries into technology-intense, service-based, and green sectors that can improve energy efficiency, decrease carbon intensity, and enhance urban environmental quality (Zhou *et al*., 2025; Ramalingam *et al*., 2025). Second, industrial structure upgrade provides technical and market space for enterprise-level green innovation, promotes the application of clean production technology and enables industrial chain greening, which forms a virtuous cycle of technological progress and economic restructuring (Hussain *et al*., 2025). Third, it promotes industries towards low-carbon, circular and sustainable development models, enhancing the overall environmental performance of industries (Yang *et al*., 2022), as well as cities' resilience to climate risks (Belaïd *et al*., 2025). Finally, high value added low carbon industrial clusters formed by structural optimization will attract green finance and policy resources, forming a virtuous cycle for urban low carbon transformation (Liu *et al*., 2023).

Being driven by the structural optimization and upgrading, industrial structure upgrading can not only enhance the overall urban economic efficiency, but also prompt the enterprises to use low-carbon technologies and management methods, which can speed up the urban low-carbon governance and green development (D. Wang *et al*., 2024). Through such a mechanism, traditional high-energy, high-emission industries gradually transform into technology-intensive, service-oriented, and green industries, thereby enhancing the energy efficiency of the industry, lowering the carbon intensity of the industry, and promoting the sustainable development of cities (Nasim *et al*., 2025). Furthermore, high value-added, low emission industrial cluster is created by industrial upgrading, which can obtain policy and green financial support to promote green infrastructure, clean energy application and ecological restoration project development. It contributes to a virtuous cycle of urban low carbon transition, and provides institutional and developmental support for economic modernization and environmental sustainability (Liu *et al*., 2024; Li *et al*., 2025).

Research is showing that a greater industrial structure upgrade is important for urban low carbon and better environmental governance. Ma(2022) found that industrial upgrade can significantly suppress urban carbon emission, through reducing the proportion of high energy intensive industry and promoting the spillover of green technology based on provincial panel data. Nasim *et al*., (2025) pointed out that high-value-added, low-emission industrial clusters help to enhance the carbon efficiency of cities and stimulate the growth of green economy. He *et al*., (2022) used data of 281 cities in China and found that the technology-driven industrial agglomeration resulting from structural optimization significantly improves urban green productivity via technological progress and green innovation, which lays a foundation for carbon efficiency improvement.

Based on the above analysis, this study proposes the following hypothesis:
H2: Industrial structure upgrading promotes urban low-carbon transformation

In the past few years, China has made significant progress toward the development of green finance reform and institution. Green finance is supported by the increase of green credit and green bonds, as well as mandatory disclosure of environmental information, to provide important financial and market incentives for low-carbon transformation during urbanization (Kouam & Catche, 2025). Empirical evidence further indicates that green finance is conducive to improvement of carbon emission efficiency and energy structure optimization in all different regions (Hu *et al*., 2023).

At the same time, industrial structure upgrade means that the economy of the city has shifted from high-energy-consuming industries to high-tech, service-oriented, green industries. This process can not only save energy and promote the spread of green innovation, but also reduce pollution (D. improve the absorptive capacity of green financial resources (Lu & Wang, 2023).

Industrial structure upgrading improves the allocation of green finance and shows “amplification” and “synergy” effects (Gao *et al*., 2022). On the one hand, a more developed industrial structure gives more clear signals of green development to financial institutions, prompting them to direct more credit towards green technology innovation and cleaner production with a higher degree of investment preference (J. Li, 2024). On the contrary, the optimized industrial structure could improve the return mechanisms of green finance, and more emission reduction results could be achieved in the low-carbon infrastructure, the renewable energy projects, and the smart-city system (K. Li *et al*., 2025). Existing studies confirm that industrial structure upgrades significantly increase the contribution of green finance to carbon reduction and improvement of environmental efficiency (Pan & Lin, 2025). So, industrial structure upgrade is supposed to exert a positive moderating influence on the link between green finance and urban low-carbon transformation.

Based on the above analysis, the following hypothesis is proposed:
H3: Industrial structure upgrading positively moderates the effect of green finance on urban low-carbon transformation.

Moreover, it can be seen from the further evidence that the moderating effect is not linear, but there are clear thresholds and asymmetrical characteristics (Hu *et al*., 2024). Moderate industrial upgrade could enhance the role of green finance in improving energy efficiency and accelerating the diffusion of green innovation. But after an industrial upgrade to a certain degree, the incrementally gained benefit will fall. Too fast upgrading could actually worsen the allocation of green finance by concentrating too much resource on the higher end sector (W. Yang *et al*., 2025). Then the influence of green finance on green innovation is stage-dependent and diminishes in marginal effects (Hu *et al*., 2024; Li *et al*., 2025). This evidence suggests that when the urban industrial structure reaches a moderate or optimal level of upgrading, green finance tends to produce the highest efficiency of innovation-inducing effects, thus forming a structural “optimal interval”. Likewise, W. Chen *et al*., (2024) identified an inverted U-shaped relationship between industrial upgrading and green development from the perspectives of knowledge diffusion and spatial heterogeneity.

Urban low-carbon transformation involves industrial coordination, technology transmission, and factor allocation (Li *et al*., 2025), and too much industrial upgrade will result in factor misallocation and weaken the spillover effect of green

elements, resulting in a reduction in the emission reduction of green finance (Gao *et al*., 2023). Therefore, it is important to capture the non-linear threshold effect of industrial structure upgrading to understand how green finance drives urban low-carbon transformation.

Based on the above discussion, the following hypothesis is proposed:
H4: The moderating effect of industrial structure upgrading exhibits nonlinear threshold characteristics. As industrial upgrading moves from lower to higher threshold levels, the positive effect of green finance on urban low-carbon transformation progressively weakens.

2.3 Government Attention, Green Finance, and Urban Low-Carbon Transformation

Government attention refers to the degree of government's policy focus, regulatory strength, and resource allocation toward environmental governance, green development, and low-carbon transition (Chen & Gao, 2025). Under the framework of ecological civilization and "dual-carbon", the degree to which a government gives due attention becomes an indispensable aspect that local governments will include as a central part of green development. Compared to traditional government attention, which focuses mainly on economic growth and investment expansion, green-oriented government attention stresses environmental performance, energy efficiency, and carbon emission control. Global climate pressure is intensifying, local governments' strengthened low-carbon policy implementation, green industrial promotion, and improved environmental governance system are widely recognized as important institutional drivers for urban low-carbon transformation (Chang *et al.,* 2022).

During the fast development of urbanization, the government's attention will greatly affect the pace and quality of urban low-carbon development by providing guidance, incentives, regulation, and improvement. (Wang *et al.,* 2025). From the one hand, enhanced government concern pushes more investment to low carbon infrastructure like green transport systems, energy efficient buildings and smart urban energy networks, which decreases carbon emission per unit of production and improves energy efficiency (Q. Li *et al*., 2021). On the contrary, government attention contributes towards the operational environment of low carbon markets by imposing emission standards, improving environmental regulation, developing green finance, which increases the willingness of the firms to adapt clean energy and low carbon technologies (Dong and Xu, 2024). Empirical research supports this, government proactiveness in environmental affairs does greatly lessen air pollutants, energy intensity and carbon discharges on urban scale, the effects being quite prolonged (X. Liu & Yang, 2022).

Although government attention is very important for promoting the progress of low-carbon transition, it is not strictly linear (Shen *et al*., 2023). Moderate policy attention levels can help to improve policy enforcement, enhance the effectiveness of regulations, and foster firm and financial institution expectations of a strong low carbon outcome. It promotes green technological innovation, industrial structure optimization, and energy system transformation (Su, 2024). However, excessive government attention will result in more policy burdens, excessive intervention, and inefficient allocation of resources, thus reducing the efficiency of the low-carbon transition (Wang *et al*., 2023). But despite this shortcoming, the existing regional- and city-level evidence generally points to a moderate and steady level of government attention as an important institutional for urban low-carbon transition (Yan *et al*., 2022).

Based on the above discussion, the following hypothesis is proposed:
H5: Government attention promotes urban low-carbon transformation.

In the promotion of urban low-carbon transformation, more and more attention is being paid by governments to the external conditions for the effectiveness of green finance (Kouam *et al*., 2025). Moderate and continuous government attention provides strong support to the resource allocation function of green finance through stabilizing policy expectations, reinforcing environmental regulation, and improving institutional environments (Zhou *et al*., 2025). The existing studies also show that governments can promote the willingness of market players to adopt green technology and low-carbon production methods by proactively participating in green infrastructure investment, building green governance systems, and enforcing environmental protection policies, thus enhancing the role of green finance in technological innovation, industrial structure upgrading, and improving energy efficiency (Xia *et al*., 2023; Su, 2024). At the same time, the government's attention will reduce the information asymmetry of green projects and improve the bankability of green projects, so that the allocation of green financial capital is more accurate and effective (D. Hu& Gan, 2025). Therefore, government attention will have a great positive moderating effect on the relationship between green finance and urban low-carbon development.

However, the moderating effect of government attention is not a strictly linear one, and it can produce very different effects at different levels (Yang *et al*., 2025). Moderate levels of policy attention increase the incentive effects of green finance (Yang *et al.,* 2025). On the other hand, if the government doesn't pay enough attention, there isn't enough institutional support either, making it hard for green finance to help with low-carbon transformation. On the contrary, too much interference by the government will increase the administrative costs, misallocate resources, or create dependence

on policy, leading to inefficiency in green finance (Wang *et al*., 2022). In other words, the moderating effect of government attention increases as it goes from a lower threshold to a higher threshold, but it could hit diminishing marginal returns past a certain point. More and more studies show that environmental policy and green development show a lot of thresholds, it's caused by the institution enforcement capability, market absorptive capability and regulation intensity together (Yıldırım *et al*., 2025). Hence, we can conclude that government attention has a non-linear threshold effect on the path of green finance to urban low-carbon transformation.

Based on the above analysis, the following hypotheses are proposed:
H6: Government attention positively moderates the effect of green finance on urban low-carbon transformation.
H7: The moderating effect of government attention exhibits a nonlinear threshold characteristic; as government attention progresses from lower to higher threshold levels, the positive effect of green finance on urban low-carbon transformation gradually strengthens.

The specific mechanism framework of this study is shown in Figure 1, with dashed arrows indicating possible moderating and threshold effects, and dashed boxes representing moderating and threshold variables.

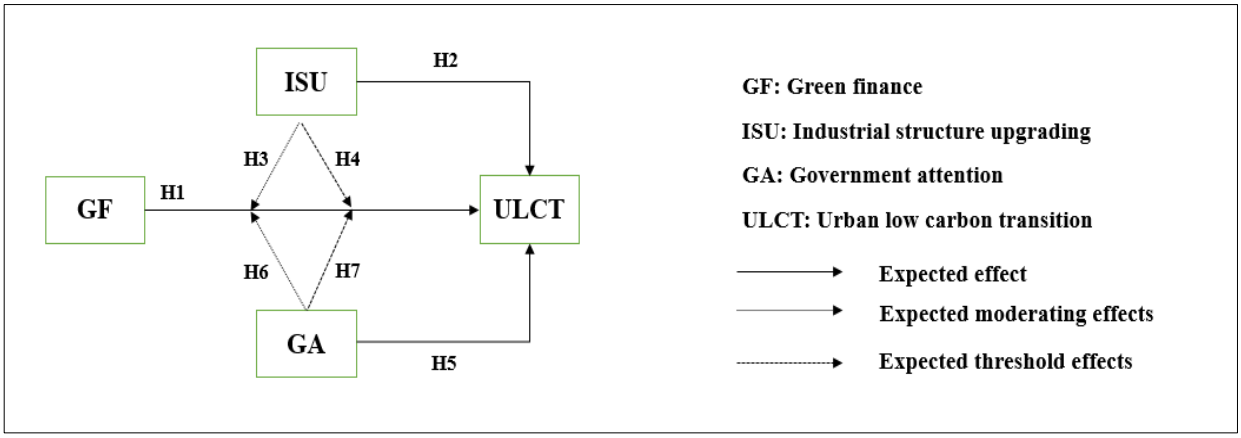


Figure 1: Conceptual framework of the impact mechanism.

3. Econometric Model and Data

3.1 Econometric Model

This study adopts a panel threshold bidirectional fixed-effect model to systematically explore the impacts of green finance, industrial structure upgrade, and government focus on urban low-carbon transformation. And also to investigate the moderating roles of industrial structure upgrading and government attention on these relationships. In view of these differences in regions and geographies, the sub-sample regression is also done to highlight the differences in detail.

First, to test hypotheses H1, H2, and H5, Models 1–3 are constructed as follows:

$$ULCT_{it} = a_0 + a_1 GF_{it} + a_2 Control_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (1)$$
$$ULCT_{it} = \beta_0 + \beta_1 ISU_{it} + \beta_2 Control_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (2)$$
$$ULCT_{it} = \gamma_0 + \gamma_1 GA_{it} + \gamma_2 Control_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (3)$$

Here $ULCT_{it}$ denotes the level of ULCT in city *i* at time *t*; GF_{it} represents GF; ISU_{it} indicates ISU; and GA_{it} refers to GA. $Control_{it}$ is a vector of control variables, such as per capita income (PGDP), resident population (POP), and foreign direct investment (FDI), and the degree of openness. δ_i and σ_t denote individual (city-specific) and time fixed effects, and ε_{it} is the error term.

In order to examine Hypotheses H3 and H6, this study further constructs the following models (4) -(5).
$$ULCT_{it} = \mu_0 + \mu_1 GF_{it} + \mu_2 ISU_{it} + \mu_3 GF_{it} * ISU_{it} + \mu_4 Control_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (4)$$
$$ULCT_{it} = \rho_0 + \rho_1 GF_{it} + \rho_2 GA_{it} + \rho_3 GF_{it} * GA_{it} + \rho_4 Control_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (5)$$

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 Hansen's (1999), this study constructs the following single-threshold regression methods (6) - (7).

$$ULCT_{it} = \vartheta_0 + \vartheta_1 GF_{it} * I(ISU_{it} \leq \gamma) + \vartheta_2 GF_{it} * I(ISU_{it} > \gamma) + \vartheta_3 Control_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (6)$$
$$ULCT_{it} = \varphi_0 + \varphi_1 GF_{it} * I(GA_{it} \leq \gamma) + \varphi_2 GF_{it} * I(GA_{it} > \gamma) + \varphi_3 Control_{it} + \delta_i + \sigma_t + \varepsilon_{it} \quad (7)$$

Here ISU_{it} and GA_{it} serve as threshold variables, γ denotes the threshold value, and GFI_{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 ULCT. The index is the ratio of total urban carbon emissions to GDP (Guo et al., 2025) which shows the efficiency of carbon emission in the economic activities. Urban low-carbon transformation can be seen as a straightforward way to calculate the "carbon cost" of economic development. Lower carbon emission intensity means the city can develop economically at a lower level of carbon emissions and therefore has a higher degree of low-carbon transformation.

3.2.2 Explanatory Variable

The explanatory variable is GF. Data come from China Statistical Yearbook and Provincial Statistical Yearbooks. The level of green finance development to a certain extent can reflect the support provided by regional financial sectors to the local clean industry. Domestic scholars tend to divide the green finance indicators into seven parts: green credit, green investment, green insurance, green bond, green fiscal expenditure, green fund and green equity (Mngumi *et al*., 2022). specifically:

1) Green credit is the proportion of loans to environmental protection projects to the total credit in the province.
2) Green investment is the proportion of investment in pollution control to GDP.
3) Green insurance: calculated as the ratio of environmental liability insurance premium to total insurance premium.
4) Green bonds, calculated as the ratio of total green bond issuance to total bond issuance.
5) Green fiscal expenditure is indicated by the ratio of environmental protection expenditure to total fiscal budget expenditure.
6) Green funds represented by the ratio of the total market value of green funds to the total market value of all funds.
7) Green equity is calculated by taking the proportion of energy and emission trading, and equity market transactions involving environmental rights, over the entire market transaction volume.

This composite index gives a full picture of how well the regional financial system supports green and low-carbon development.

3.2.3 Moderating and Threshold Variables

ISU is a general term referring to all universities or colleges in Iowa, United States. Following H. Cheng (2025), industrial structure upgrading is defined as the ratio of the value added of the tertiary industry to the secondary industry. This ratio shows how much the economy moves away from making things and using resources towards providing services and getting more money for what it does.

GA. Government attention is measured with a text-mining approach (Ding *et al*., 2023; Yu *et al*., 2024). specifically, it is calculated as the ratio of the number of words containing the terms “green”, “low-carbon”, and “environmental protection” in the provincial government work reports to the total number of words in the reports. This indicator represents the degree of policy attention and regulatory emphasis that local governments give to green development and low-carbon transformation.

3.2.4 Controls Variables

Per Capita Income (PGDP). This indicator represents the total ability of people in a region or country to consume goods and services during a certain period of time, showing the role of consumption in economic activities (Jafar *et al*., 2025). Following Brühl (2024) we measure it as the ratio of total retail sales of consumer goods to regional GDP.

Resident population (POP). This index reflects the actual size of a city and the degree to which people are concentrated, indicating the economic vitality and resource and environmental pressure of a city (Yang *et al*., 2025). Following Qiao and Huang (2024), it is measured by the end-of-year resident population of the region.

Foreign Direct Investment (FDI). This is an indicator of a regions ability to attract foreign capital and a reflection of a regions open economy and industry. Following Guo *et al*., (2024), it is measured by the actual flow of FDI in the region.

3.3 Data

Regarding the data available for this study, the 261 cities in the mainland of China were used from 2006 to 2023. Definitions of variables and data sources are given in Table 1.

Table 1: Variable definitions and data sources

Variable	Symbol	Measure	Data sources
Green Finance	GF	Composite index constructed using the entropy method from seven green finance indicators	China Statistical Yearbook
Urban Low-Carbon Transformation	ULCT	Ratio of carbon emissions to GDP	China Statistical Yearbook
Industrial Structure Upgrading	ISU	Ratio of value added of the tertiary sector to the secondary sector	China Statistical Yearbook
Government Attention	GA	Text-mining method: proportion of keywords such as "green", "low-carbon", and "environmental protection" in provincial government work reports relative to total word count	Provincial Government Work Reports
Per Capita Income	PGDP	Regional GDP divided by year-end resident population	China Statistical Yearbook
Resident Population	POP	Year-end resident population of the region	China Statistical Yearbook
Foreign Direct Investment	FDI	Actual inflow of FDI in the region	China Trade and Economic Statistics Yearbook

Source: *Authors' own work*

All variables are first tested for a unit root. Non-stationary series are transformed through first order differencing. Post transformation result confirms that all the variables are stationary. Multicollinearity is further checked by VIF, and there are no issues with multicollinearity. The relevant results can be seen in Tables 2 and Table 3. All variables were winsorized at the 1% level to reduce the influence of outliers. Analysis done in Stata 18.

Table 2: Variance Inflation Factor (VIF) Test

Variables	VIF	1/IVF
PGDP	2.23	0.447867
POP	2.16	0.463334
ULCT	2.13	0.469662
FDI	2.09	0.479148
GA	1.27	0.789825
IS	1.17	0.856737
Mean VIF	1.84	

Source*: Authors' calculation*

Table 3: Descriptive Statistics Results

Variables	Obs	Mean	SD	Min	Max
GF	4698	1.11	0.40	2.06	1.97
ULCT	4698	3.65	3.48	0.06	50.22
IS	4698	1.01	0.57	0.13	6.39
GA	4698	0.12	0.10	-0.09	1.74
PGDP	4698	10.58	0.71	8.25	12.24
POP	4698	5.94	0.69	4.03	8.07
FDI	4698	5.29	1.88	3.51	10.10

Source: Authors' calculation

4. EMPIRICAL RESULTS AND DISCUSSION

4.1 Fixed Effects Model

In this study, a two-way fixed effects panel is used to estimate models (1) - (5) and to test hypotheses H1, H2, H3, H5 and H6. Table 1 is the regression result.

Table 1: The regression results

ULCT	(1)	(2)	(3)	(4)	(5)
GF	0.6501*** (0.1767)			2.1499*** (0.2136)	0.9470*** (0.1997)

ISU		0.1249** (0.060)		2.0653*** (0.1541)	
GA			1.2682*** (0.2413)		3.8381*** (0.6220)
GF*ISU				-1.5649*** (0.1096)	
GF*GA					-2.4764*** (0.5294)
PGDP	-2.620*** (0.0643)	-2.475*** (0.0444)	-2.5656*** (0.0466)	-2.688*** (0.0631)	-2.7497*** (0.0671)
POP	3.291*** (0.622)	3.1648*** (0.6228)	2.8768*** (0.6173)	3.994*** (0.6124)	3.3289*** (0.6223)
FDI	-0.0375* (0.0211)	-0.0378* (0.0213)	-0.0350* (0.0211)	-0.0383* (0.0209)	-0.0338 (0.0211)
Cons	11.293*** (3.7331)	11.112*** (3.7470)	13.7295*** (3.7447)	5.9298 (3.6781)	11.9804 (3.7462)
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√
N	4698	4698	4698	4698	4698
R square	0.4984	0.4974	0.5000	0.5205	0.5034

Note: *p<0.1; **p<0.05; ***p<0.01

From the results of Models 1, 2, and 3 in Table 4, we can see that the green finance has a significant positive impact on the transformation of urban low-carbon; Industrial structure upgrading and government attention also have a significant positive effect on the transformation of urban low-carbon. The three regression coefficients are 0.6511, 0.1249, 1.2682 respectively, and they are all significantly at the 1% level. It can be concluded that all factors can significantly promote urban low carbon transformation, which is consistent with the result of Zhang *et al*., (2023). So, the hypotheses H1, H2 and H5 are supported.

Model 4 is the interactive effect of green finance and industrial structure upgrading. The coefficient of GF*ISU is -1.5649 and is significantly negative at the 1% significance level, which shows that industrial structure upgrading has a negative moderating effect on the impact of green finance on urban low-carbon transformation, which is contrary to Hypothesis H3. Some possible reasons have been suggested: First, the transformation of industrial structure into green has not been completely realized. Some places, even if the economic structure changes from secondary industry to tertiary industry, high energy consumption and high emission industries are still the main body, and the situation of "upgrade but not green" is still there. Secondly, the green finance investment does not necessarily flow effectively into low-carbon industry; Secondly, there are great transformation costs in the process of industrial structure upgrading. Upgrading often goes together with the renewal of the equipment, updating the technology, and substituting the industry. This can lead to an increase in intensity of energy consumption and carbon emission for a certain period of time. Therefore, the positive incentives of green finance may be offset in the short term; Third, the allocation efficiency of green finance is still limited. In areas where industries have advanced structures, green finance resources tend to be concentrated in large projects and traditional infrastructure, while financing for small and medium-sized green innovation enterprises is restricted. It leads to poor allocation efficiency of green finance resources, which hinders the synergy between green finance and industrial structure upgrading to drive low-carbon transformation.

From the results of model 5, we can see the interaction between green finance and government attention. The coefficient of GF*GA is -2.4764, which is significantly negative at the 1% significance level, suggesting that government attention has a negative moderating effect on the impact of green finance on urban low-carbon transformation, contradicting hypothesis H6. Several possible explanations are put forward, the first one being: Policy orientation bias. When the government overemphasizes carbon reduction and green development goals, green finance resources are inclined towards administrative or short-term performance-oriented projects, resulting in resource misallocation and reducing the effectiveness of the actual low-carbon transformation. Second, resource congestion effect. Third, implementation lag. When the government vigorously promotes green projects, the rapid growth of green finance supply, intensified competition among projects, and scattered funding may lead to lower-quality projects, thus diminishing the marginal benefits of green finance. Although the attention of the government has increased, regulatory and market-based methods are not completely established, so it is not easy to make full use of the resources of green finance, which restricts the role of green finance in promoting urban low-carbon transformation. Fourth, market distortion effect. Government intervention causes green finance to drift away from the market's efficient investment areas, making the investment direction a result of policy rather than market, thereby diminishing the effect of green finance on promoting the low carbon transformation.

4.2 Threshold Regression

According to the results of models 4 and 5, this paper adopts the box estimation and Wald test method to discover the nonlinearity and threshold effect of the moderating effects. Results are given in Table 5. Specifically, the results shown in Table 5 show that Model 6 has a double threshold structure and Model 7 has a single threshold with a large effect. Therefore, this paper only does threshold regression for model 6, and the estimation results are shown in table 6.

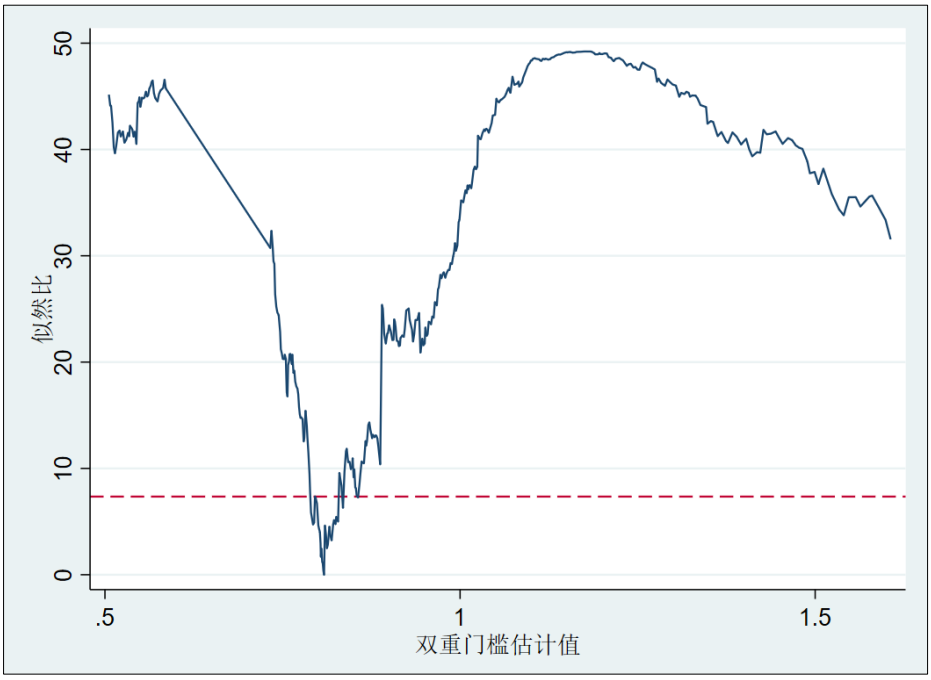
Table 5: Threshold Effect Test Results

Model	Variables	Type	Values	p-values	95% Conf.Interval
（6）	ISU	Single	0.7930	0.0000	[0.7883,0.7946]
		Double	0.8085	0.0000	[0.8016,0.8098]
（7）	GA	Single	0.1417	0.003	[0.1203,0.1423]
		Double	no	no	no

Table 6: Threshold effects regression results for ISU variables

Model	Coefficient	Standard Error	T value	P value
GF*ULCT(ISU<0.7930)	-0.4358*	0.2474	-1.76	0.079
GF*ULCT(0.7930≦ISU <0.8085)	0.0326	0.2478	-0.13	0.895
GF*ULCT(ISU≥0.8085)	0.3110	0.2550	1.22	0.224
PGDP	-2.635***	0.183	-14.59	0.000
POP	3.785**	0.255	1.69	0.092
FDI	-0.087	0.036	1.22	0.224
Year-fixed effect	√	√	√	√
City-fixed effect	√	√	√	√
Observations	4698			
Number of id	261			
R-squared	0.5065			

Noted：*p＜0.1，**p＜0.05，***p＜0.01



Model 6 shows that industrial structure upgrading has a double threshold effect on the influence of green finance on urban low-carbon transformation. In particular, when the level of industrial structure upgrading is very low (less than 0.793), the effect of GF on ULCT is negative and statistically significant at the 10% level. It indicates that in the early stage of the industrial structure upgrading, green finance can also restrain the urban low-carbon transformation. One possible reason is that at a low level of upgrading, industries are still mainly composed of high-energy-consuming and high-emission industries, and green finance resources are often used to support traditional sector-level technological upgrades instead of fundamental green innovations (Kumar *et al*., 2024).

When ISU is within a moderate range of 0.793-0.8085, GF starts to take on a positive value but it is not statistically significant, which means that although industrial structure upgrades have been progressing, green finance and urban low-carbon transformation have not aligned sufficiently. Green finance has not yet permeated strategic emerging industries at this stage, the transmission mechanism of policies is not complete, which restricts the facilitation of green finance (Zeng *et al*., 2022).

When ISU is greater than 0.8085 (high), although the positive effect of GF is not significantly effective, it tends to be positive, indicating that as the industrial structure becomes more and better, the positive effect of green finance is also getting stronger. The upgrading of industrial structure can improve the allocation efficiency of factors and the capacity of technological innovation, making green finance resources flow more and more to low carbon, energy saving and clean energy industries, so as to enhance the impetus of urban low carbon transformation (K. Li *et al*., 2025).

In summary, under low levels of industrial structure upgrading, the agglomeration of industries towards energy-intensive and emission-intensive sectors constrains the efficiency of green finance resource allocation, exerting a negative influence on urban low-carbon transformation (Xia *et al*., 2024). At a moderate level of upgrading, a synergy starts to appear between green finance and emerging industries, some green finance flows are directed towards energy saving and environmental protection areas; but because of insufficient technological innovation and poor transmission mechanism, its promotion is not stable (X. Liu and Zhang, 2023). When the level of industrial structure upgrade is at a higher level, the industrial system is more optimized, and the guiding role of green finance to support clean energy, green manufacturing, and other industries becomes more obvious, and it gradually transforms into an important force promoting urban low-carbon transformation (Nepal *et al*., 2024). And this conclusion is consistent with Gao, (2023) which confirms that optimizing industrial structure is an urgent need for green finance to reach low-carbon effect.

4.3 Heterogeneity Analysis on Different Geographic Locations

Given the uneven regional development across China and differences in regional industrial structures and green development policy implementation intensity, there are regional differences in ISU and GA(X. YU, ZHENG, 2023. To investigate whether the effects of GF on ULCT vary depending on regional differences in ISU and GA, as in Gao *et al*., (2024), the sample is separated into three large regions: East, Central, and West China. Then, panel threshold regressions are run separately for each of the regional subsamples. Table 7 shows the results.

Table 7: Regional Heterogeneity Regression Results

Variables	Eastern		Central		Western	
GF	2.4032*** (0.3157)	-0.0738 (0.2932)	2.4582*** (0.4336)	1.3430*** (0.4148)	1.3069*** (0.3602)	1.3296*** (0.3390)
ISU	0.2191 (0.3562)		3.3291*** (0.3038)		2.0019*** (0.2398)	
GA		-2.5759 (1.8014)		6.9190*** (1.5868)		6.0213*** (0.9036)
GF*ISU	-0.6875*** (0.2202)		-2.4331*** (0.2282)		-1.3562*** (0.1985)	
GF*GA		2.5643** (1.2965)		-5.75011*** (1.4994)		-6.2796** (0.8858)
controls	ok	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√	√
City-fixed effect	√	√	√	√	√	√

Note：*p＜0.1，**p＜0.05，***p＜0.01

According to the regional heterogeneous regression results, the interaction between GF and GA is significantly negative in the eastern region in the base regression, while it turns to significantly positive in the central and western regions. Which means that the government's attention to the promotion of urban low-carbon transformation through green finance has different levels of moderation across regions. In particular, in the eastern region which is economically developed and has a well established financial system, local governments have clear policy orientations and regulatory efficiency in the field of green development is relatively high., this makes it possible for green finance resources to be effectively directed toward low-carbon areas like green infrastructure and clean energy, which will in turn further strengthen the facilitation of green finance on the low-carbon transformation of cities (K. Li *et al*., 2024).

Conversely, in the Central and Western regions, limited fiscal funds, weak environmental governance capability, underdeveloped green financial markets, etc., result in greater government attention taking on the form of administrative intervention. This can reduce the efficiency of the market, cause resource waste, and weaken the positive effect of green finance on the low-carbon transformation (Z. (Zhang *et al*., 2023).

As a whole, the "directional effect" of government attention has obvious regional characteristics, that is to say, the promotion effect of green finance on low-carbon, if the policy orientation is consistent with the market mechanism, then the green finance promotes the low-carbon; Otherwise, it will weaken the effectiveness of green finance or even cause negative effects.

4.4 Robustness Test

4.4.1 Dynamic Adjustment Test

There may be a bidirectional relationship between industrial structure upgrading and urban low-carbon transformation, and between government attention and urban low-carbon transformation, leading to endogenous issues and possibly biasing the model estimates. To reduce the influence of such a reverse effect, this paper follows Wang (2024) to use one-period lagged value of the main explanatory variables as the model. The specific regression results can be seen in Table 8, showing the robustness of these findings.

Table 8: One-Period Lagged Fixed Effects Regression Results

ULCT	(1)	(2)	(3)	(4)	(5)
GF	1.1521*** (0.2026)			2.3371*** (0.2410)	1.2660*** (0.2192)
ISU		0.2551*** (0.0633)		1.9237*** (0.1629)	
GA			1.3083*** (0.2460)		3.3172*** (0.6466)
GF*ISU				-1.4204*** (0.1189)	
GF*GA					-2.0706*** (0.5518)
Controls	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√

Note： *p＜0.1，**p＜0.05，***p＜0.01

4.4.2 Extreme Value Trimming Test

To exclude the effect of extreme values from the results as Li *et al*., (2025b) did, we excluded the top and bottom 1%, 5%, and 10% of IS and GA values. Excluding these extreme observations, different subsamples are formed, and grouped regression analysis is carried out to verify the robustness of the conclusions. The regression results for these are shown in tables 9-14 and the results are robust.

Table 9: IS - Excluding Top and Bottom 1% Extreme Values

ULCT	(1)	(2)	(3)	(4)	(5)
GF	0. 6961*** (0.1790)			2.0908*** (0.2241)	0.9928*** (0.2020)
ISU		0.2553*** (0.0642)		2.0434*** (0.1597)	
GA			1.2370*** (0.2446)		3.753*** (0.6265)
GF*ISU				-1.5266*** (0.1195)	
GF*GA					-2.4459*** (0.5352)
Controls	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√

Note: *p＜0.1，**p＜0.05，***p＜0.01

Table 10: IS - Excluding Top and Bottom 5% Extreme Values

ULCT	(1)	(2)	(3)	(4)	(5)

GF	0. 9387*** (0.1841)			1.5049*** (0.2427)	1.2306*** (0.2028)
ISU		0.6316*** (0.0642)		1.8304*** (0.1818)	
GA			1.3107*** (0.2446)		3.7425*** (0.6405)
GF*ISU				-1.0829*** (0.1443)	
GF*GA					-2.4084*** (0.5506)
Controls	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√

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

Table 11: IS - Excluding Top and Bottom 10% Extreme Values

ULCT	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
GF	0. 9387*** (0.1841)			1.5049*** (0.2427)	1.2306*** (0.2028)
ISU		0.6316*** (0.0642)		1.8304*** (0.1818)	
GA			1.3107*** (0.2446)		3.7425*** (0.6405)
GF*ISU				-1.0829*** (0.1443)	
GF*GA					-2.4084*** (0.5506)
Controls	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√

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

Table 12: GA - Excluding Top and Bottom 1% Extreme Values

ULCT	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
GF	0.6380*** (0.1797)			2.1399*** (0.2170)	0.9545*** (0.2033)
IS		0.1252*** (0.0624)		2.1141*** (0.1597)	
GA			1.2801*** (0.2471)		3.9684*** (0.6314)
GF*ISU				-1.5898*** (0.1128)	
GF*GA					-2.5970*** (0.5391)
Controls	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√

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

Table 13: GA - Excluding Top and Bottom 5% Extreme Values

ULCT	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
GF	0.6246*** (0.1885)			2.0860*** (0.2277)	0.8835*** (0.2137)
ISU		0.1319*** (0.0654)		2.1562*** (0.1707)	
GA			1.523*** (0.2737)		4.0179*** (0.6699)

ULCT	(1)	(2)	(3)	(4)	(5)
GF*ISU				-1.6030*** (0.1197)	
GF*GA					-2.4030*** (0.565)
Controls	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√

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

Table 14: GA- Excluding Top and Bottom 10% Extreme Values

ULCT	(1)	(2)	(3)	(4)	(5)
GF	0.5890*** (0.2010)			2.0901*** (0.2400)	0.8926*** (0.2271)
ISU		0.0538*** (0.0699)		2.0607*** (0.1796)	
GA			1.909*** (0.325)		5.0755*** (0.7704)
GF*ISU				-1.5900*** (0.1255)	
GF*GA					-2.9181*** (0.6209)
Controls	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√

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

4.4.3 Additional Control Variables

In order to better confirm the robustness of the results, this paper has carried out another robustness test, adding one more control variable to the original model. Environmental regulation (ER) is added as a new control variable to explore its influence on the regression results. The results are displayed in table 15 and they support the findings.

Table 15: Robustness Test Results with Additional Control Variable (ER)

ULCT	(1)	(2)	(3)	(4)	(5)
GF	0. 6311*** (0.1769)			2.1334*** (0.2137)	0.9296*** (0.2000)
ISU		0.1196*** (0.0603)		2.0598*** (0.1541)	
GA			1.2426*** (0.2416)		3.7925*** (0.6226)
GF*ISU				-1.5629*** (0.1096)	
GF*GA					-2.4517*** (0.5295)
Controls	ok	ok	ok	ok	ok
Year-fixed effect	√	√	√	√	√
City-fixed effect	√	√	√	√	√

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

5. CONCLUSION

5.1 Key Findings

This paper uses panel data from 261 Chinese cities during 2006-2023, which are panel threshold bidirectional fixed-effects models to analyze how green finance impacts urban low-carbon transformation through industrial upgrading and government attention. Main findings:

Firstly, green finance, industrial transformation, and government attention can all promote the urban low-carbon transformation. Secondly, industrial upgrading and government attention are both negatively moderated in the process of

green finance promoting urban low-carbon transformation. Lastly, the moderating effects of industrial upgrading and government attention on the impact of green finance are also heterogeneous in different regions.

5.2 Discussion

The empirical results from this study generally align with the research hypotheses that have been put forward, even though some of the individual findings do not conform to what was anticipated. We would have to talk a lot more if we wanted to understand the root causes and meanings of these various outcomes better.

5.2.1 Main Effects Perspective

The empirical results show that the three aspects of green finance, industrial upgrading, and government attention are all very significant for promoting the overall progress of urban low-carbon transition. This is mostly in line with what other papers have found, so it means that giving green money to nature stuff, making better jobs for factories and stuff like that, and when the city helps out more, all these things are important for making a greener, low-pollution city (Kouam & Catche, 2025; R. (Wang *et al*., 2025). Empirically speaking, this study demonstrates the Chinese policies that promote the allocation of green factors based on the market, optimize the investment structure of resources, and promote high-quality low-carbon development. Among them, industrial upgrading plays an important supporting role in improving the efficiency of urban green development through the guidance of industries to high-tech, high-value-added, and low energy consumption sectors, improving the efficiency of resource utilization and reducing the lock-in effect of high emission industries, thus effectively promoting the low carbon transition of cities (Gao *et al*., 2023). Government focus then greatly improves cities' abilities for technological progress, governing efficiency, and development of green infrastructure by pushing forward policy execution, increasing the efficiency of public resource allocation toward green sectors, and intensifying environmental control, which improves the internal push for urban low-carbon transformation (Y. Zhao *et al*., 2022; P. Cheng & Gao, 2025).

5.2.2 Moderating Effects Perspective

From the aspect of moderating effects, this paper finds that both industrial upgrading and government attention have significant negative moderating effect on the promotion of urban low-carbon transition by green finance. This means that in cities where the industrial upgrade is at a high level or the government has a strong emphasis on environmental issues, the promoting effect of green finance on urban low-carbon transition becomes smaller. On the other hand, although the industrial system has a positive impact on urban green development, when industrialization has reached a certain level, it is difficult to significantly optimize the scope of resources and efficiency through green finance. The effect of green finance on low-carbon transition will decrease. In other words, the closer the industrial structure is to high-end and low-carbon industries, the smaller the additional incentive effect of green finance. In contrast, a higher government attention level implies tighter policy constraints, environmental regulations, and performance evaluation mechanisms, which means part of the low-carbon transition momentum comes more from administrative force rather than money. In this situation, the marginal effect of green finance is partially replaced by strengthened administrative means, and it has a negative moderating effect.

5.2.3 Heterogeneity Perspective

The effect of green finance on the urban low-carbon transition is consistent in different areas. In the east, because there is an established financial market, an advanced industrial structure, and a strong government, government attention can work together well with market forces, so the positive effect of green finance in driving low-carbon transformation is greatly increased. This finding is consistent with the heterogeneity regression, in which the interaction term in the eastern region changed from negative to positive, indicating that "well-established institutions-effective market-policy gain". On the contrary, in the central and western region, the green finance system is still under construction and industrial structure is relatively fragile, and the government's attention to green finance is mainly reflected as a form of administrative supervision or redistribution of resources, without market-based incentives. In this case, government attention will not only fail to enhance the low carbon effect of green finance, but may also worsen resource misallocation and increase market transaction costs, thus weakening or even inhibiting the promoting effect of green finance.

6. Theoretical Contributions and Policy Implications

6.1 Theoretical Contributions

First, this study extends the relevant green finance studies that mostly focus on energy, manufacturing or environmental performance into a framework of urban low-carbon transition. Through building a green finance- industrial structure upgrading - government attention integrated analysis framework, the paper systematically elucidates the mechanisms of how green finance facilitates urban green development through capital, technology and institution. It also enriches the theoretical foundation of green finance in urban governance and low-carbon city construction. The study not only explains the effect of green finance on the optimization of urban energy structure, the development of green infrastructure and the formation of low-carbon urban life style, but also provides a new theoretical perspective and analytical model to understand urban low-carbon transition.

Second, it breaks away from the traditional assumption of linearity for the moderating role of industrial structure upgrading and government attention. It highlights that there is complexity and contingency in the moderating role of industrial structure upgrading and government attention during the process of green finance supporting urban low-carbon transition. From a context-dependent perspective, it shows for the first time that industrial structure upgrading and government attention can, under certain conditions, weaken rather than strengthen the low-carbon effects of green finance. This means that how well green finance works depends a lot on local industrial development, how the government runs things, and whether markets are set up to work freely. It challenges the theoretical assumption of the traditional structure upgrading and government attention necessarily promoting green development, providing new theoretical enlightenment to the interaction mechanism of green finance, institutional context and structural change, and providing empirical evidence for the theory of optimal institutional environment.

Third, this study identifies considerable structural diversity in the impact of green finance between eastern, central and western regions, and offers a tripartite framework of institutional quality, market maturity, and administrative intervention to explicate the underpinnings. The results show that government attention has a positive moderation effect in the east, strengthening the effect of green finance, while it has a weak or negative effect in the central and western regions. This shows that green finance has different effects in different places. It challenges the universality assumption of green finance in promoting low-carbon transition and stresses that institutional environment, governance capacity and economic foundation affect the marginal effects of green finance policies. It can provide essential theoretical basis to formulate regionally adaptive green finance theories and differentiated low carbon policies.

6.2 Policy Implications

6.2.1 From the Perspective of GF Promoting ULCT

To better use green finance to promote urban low carbon transition, local governments need to develop differentiated green finance policies according to their own development stages and industry characteristics. As for the eastern region, efforts should be made to further improve the efficiency of allocating green financial resources, and direct these resources towards green infrastructure construction, clean energy projects, and urban green transportation systems, so as to consolidate the eastern region's leading position in low-carbon development. As for the central region, it should focus on improving the green regulatory system, increase the transparency and standardization of green funds use, avoid resource allocation caused by excessive administrative intervention. In the west, improving the green project financing accessibility by providing green finance through fiscal incentives, dedicated funds, and green credit is necessary to attract better quality green investments.

Meanwhile, all regions should improve the green taxation policy system, use tax incentives, exemptions, and reward methods to reduce the cost of developing a low-carbon industry and enhance the combination of green finance and fiscal policy. Goverments should also strengthen the innovation of green technological, build inter-regional green technology sharing mechanism and leverage green finance to support research, development and commercialization of green technology. This can help to better implement low-carbon technologies in urban industries and public service systems. Through coordination of institutional, financial and technical mechanisms, the drive of green finance is intensified, and urbanization is directed towards greener, lower-carbon and sustainable paths.

6.2.2 From the Perspective of the Moderating Role of ISU

From the perspective of the industrial upgrading moderating effect, it has non-linear and context-dependent effects on green finance in the promotion of urban low-carbon transition. Some areas are not aligned with industrial upgrading and the direction of green finance, causing a misalignment between industrial capital and green capital, which will weaken the positive effect of green finance on low-carbon transition. Therefore, it is necessary for local governments to integrate green orientation into industrial planning and policy framework during the process of industrial upgrading. Industrial upgrading can be made compatible with the low carbon goals of green finance through strategic planning, entry standards, and environmental constraints. On the one hand, it is necessary to enhance the green restructuring of industrial chains, speed up the green transformation and digitalization of high energy consumption industries, so as to weaken the structural friction that reduces the effectiveness of green finance.

And at the same time, each region should cultivate regional green industry foundations according to its own conditions to enhance the absorptive effect and amplifying effect of industrial upgrading on green finance. In the east, efforts should be concentrated on rapidly advancing high-end service industries and green tech industries to create more opportunities for green finance investments. In the central region, support for green manufacturing and clean production should be increased to raise the real "green content" of industrial upgrading. In the west, industrial development must use local resource advantages to develop renewable energy, eco-tourism, and green specialty industries, and avoid taking upgrading roads ahead of time that do not fit with the local foundation. By improving the interactive mode of industrial

upgrading and green finance, the support capacity and developmental strength of industries for urban low-carbon transition can be effectively improved.

6.2.3 From the Perspective of the Moderating Role of GA

Moderation from government attention's perspective reveals the impact on green finance to urban low-carbon transition has strong regional difference and context dependency. The eastern region can have government attention effectively cooperate with the market mechanism. Through more open policy guidance, a stronger regulatory system, and a more efficient administration, it further enhances the low-carbon promoting effects of green finance. Therefore, the eastern region should continue to play the guiding role of the government in green development by enhancing policy stability, improving the disclosure of green finance, and improving the green project evaluation framework. It can also reinforce the policy synergy of promoting urban green transition through green finance by building a good and transparent government supervision environment.

In contrast, in the central and western regions, government attention to some extent may reduce the role of green finance with strong administrative intervention, low governance capability, and immature green finance markets. Local governments must improve the professional level of carrying out green finance policies to avoid the waste caused by "over-attention" and to minimize the damage of superficial or campaign-style environmental projects. The central and western areas need to concentrate on improving their green governance ability, improve the environmental information disclosure, and improve the accuracy of regulation. And also train, innovate institutionally, and carry out collaborative projects with the east to improve the capacity of policy implementation. Governmental attention can become more normative and professional by aligning governmental guidance with market signals, which would improve the efficiency of green finance transmission and support the strong development of urban low-carbon transition.

6.2.4 From the Perspective of Heterogeneities

In terms of regional heterogeneity, there is a great disparity in the promotion of green finance for the urban low-carbon transition in different regions, indicating that the marginal effects of green finance depend on the institutional environment, industrial base, and the development level of the financial system. In the east, where the financial system is more mature and the level of marketization is high, green finance can form a virtuous synergy with local governance structure. Therefore, it is recommended to continue deepening green finance innovation pilots and to expand the use of green finance tools such as green credit and green bonds for urban green infrastructure construction, energy structure adjustment, and green transportation to enhance the amplification effect of green finance on low-carbon transition.

In the central and western region, strengthen the financial governance foundation, strengthen the environmental governance foundation. To achieve this, it is necessary to improve the green project evaluation system, improve the quality of information disclosure, and strengthen green supervision, so as to alleviate the negative impact of administrative intervention on the efficiency of green capital allocation, and make sure that green finance truly serves the purpose of low-carbon development.

Additionally, each region needs to develop its own unique pathway for the development of green finance in line with its own developmental stage. The eastern region could prioritize developing a green finance standard system, export governance experiences to other regions and achieve linkage effects. The central region needs to optimize its industrial structure and improve the quality of green project portfolios while improving the capacity of green finance resources through introducing specialized financial institutions and green funds. Western regions should take advantage of the national policies to give more support to the green infrastructure and renewable energy industries, attract more green capital by fiscal subsidies, sharing risks and cross-regional cooperation. Through creating a regional specific green finance policy system, we can maximize the overall contribution of green finance to the urban low carbon transition of China.

7. Limitations and Directions for Future Research

There maybe many factors that affect the relationship between green finance and urban low-carbon transition. In this study, the moderating factors considered were only industrial structure upgrading and government attention. Future research could look into other possible determinants that could influence this relationship.

And this study used a panel two-way fixed effects model to explore the relationships among the variables. Future studies can use other methods such as coupling coordination model or game-theoretical approach to further explore and improve our knowledge of green finance promoting urban low-carbon transition.

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