frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 17 December 2025
DOI 10.3389/fenvs.2025.1715947

OPEN ACCESS

EDITED BY
Angeliki N. Menegaki,
Hellenic Mediterranean University Research Centre, Greece

REVIEWED BY
Sandeep Poddar,
Lincoln University College, Malaysia
Dimitrios Tsiotas,
Agricultural University of Athens, Greece

*CORRESPONDENCE
Wei Xi,
qingtingxixi1957@163.com

RECEIVED 24 November 2025
REVISED 02 November 2025
ACCEPTED 28 November 2025
PUBLISHED 17 December 2025

CITATION
Zhu H and Xi W (2025) The green entrepreneurial boom: how China's low-carbon policies are reshaping urban economies. *Front. Environ. Sci.* 13:1715947. doi: 10.3389/fenvs.2025.1715947

The green entrepreneurial boom: how China's low-carbon policies are reshaping urban economies

Honggen Zhu[1] and Wei Xi[2]*

[1]School of Economics, Nanjing University of Finance and Economics, Nanjing, Jiangsu, China, [2]Institute of Food and Strategic Reserves, Nanjing University of Finance and Economics, Nanjing, Jiangsu, China

Low-carbon policies represent a crucial initiative and primary pathway for China's low-carbon transition, holding significant importance for green economic development. Building upon an analysis of the implementation context of low-carbon policies, this study employs a two-way fixed effects model to empirically evaluate the impact of these policies on urban green entrepreneurship using Chinese city panel data from 2007 to 2022. It further examines the mechanisms through which low-carbon policies influence urban green entrepreneurship. Results indicate that low-carbon policies exert a significant positive impact on urban green entrepreneurship, promoting it through both green innovation incentives and green consumption drivers. Across geographically distinct cities, these policies show a weaker effect on green entrepreneurship in Northwest China compared to Southeast China. Among cities with varying characteristics, the policy's boost to green entrepreneurship is more pronounced in cities with lower financial development levels. Therefore, China should further promote low-carbon policies, actively explore personalized green development models tailored to urban characteristics, optimize the policy environment for low-carbon industries, and enhance green innovation mechanisms. Concurrently, it should vigorously promote green development concepts, guide public green consumption, and foster urban green entrepreneurship.

KEYWORDS

low-carbon pilot, green entrepreneurship, net effect, policy intensity, environmental regulation

1 Introduction

As a fundamental environmental regulatory policy, the low-carbon city pilot program poses a crucial academic challenge at this crucial point in the low-carbon transition: Can it make synergistic progress in social justice and environmental benefits? For cities that are the main sources of carbon emissions, this is especially important. According to research, low-carbon policies' main goals are to optimize energy structures, reduce emissions and conserve energy, encourage green innovation, upgrade low-carbon industrial systems, facilitate the low-carbon transformation of high-pollution sectors, improve ecological efficiency, and eventually achieve high-quality urban development (Hua et al., 2020; Wang et al., 2022; Seshadri et al., 2025). The main elements of low-carbon policies include developing strategies for low-carbon growth, enacting laws to support low-carbon development, and setting up a system for statistically tracking greenhouse gas emissions (Zhang, 2022; Amin, 2025). These regulations are an essential component of the framework for environmental policy (Cheshmehzangi, 2021).

One of the main forces behind the economic growth of green cities is green entrepreneurship, a new economic activity that tackles environmental issues while producing both commercial and environmental value (Mondal et al., 2025). However, green entrepreneurship is prone to being influenced by policy environments and institutional frameworks due to its high investment requirements and systemic barriers. Therefore, is the low-carbon policy a contributing factor to the rise in urban green entrepreneurship? What is the fundamental mechanism involved? This is an important topic for discussion in the context of low-carbon development and the growth of green economies in urban areas.

Existing research has examined the relationship between environmental policies and entrepreneurial activities. The vast majority of scholars believe that environmental regulations promote green innovation and entrepreneurial activities (Li et al., 2025; Hassan et al., 2025). Environmental regulations play a crucial role in sustainable entrepreneurship. As a series of regulatory measures and policies established by governments to protect the environment and reduce resource waste, environmental regulations exert a positive influence on the economic activities of start-up enterprises, thereby promoting green innovation among new ventures (Carchano et al., 2024). Some scholars argue that environmental regulations may hinder entrepreneurial activities, with informal environmental regulations exerting a significant inhibitory effect on green innovation (Xu et al., 2022; Bu et al., 2024). These researchers primarily examine the issue from the perspective of corporate competitiveness, positing that environmental regulations, as constraints on business decision-making, increase production costs, reduce corporate competitiveness, and thus discourage enterprises from engaging in entrepreneurial activities (Cojoianu et al., 2020).

Additionally, many scholars have evaluated the effectiveness of low-carbon policy implementation. Research indicates that low-carbon policies can effectively reduce urban carbon emission intensity, with this impact exerting a sustained driving force (Siregar et al., 2024). The implementation of low-carbon policies effectively promotes carbon reduction and enhances energy efficiency, thereby boosting the growth of urban green total factor productivity (Zhang et al., 2025). Concurrently, low-carbon pilot policies contribute to improving enterprises' technological innovation capabilities (Raihan et al., 2022).

A review of the literature reveals that the relationship between low-carbon policies and urban green entrepreneurship is complex, exhibiting both promotional and inhibitory effects. On the one hand, the low-carbon city pilot program has constrained the development of high-pollution, high-emission industries, compelling these sectors to transform and innovate in order to meet policy requirements (Mehmood et al., 2024). On the other hand, the preferential policies for clean and environmentally friendly industries under the low-carbon city pilot program provide crucial support for entrepreneurship in these sectors (Huang et al., 2022).

In reality, the impact of low-carbon policies and environmental regulations on entrepreneurial activity is complex. While such policies can stimulate the establishment of new enterprises, they also lead to the exit of outdated production capacity. In light of this, this study aims to investigate and pinpoint the underlying processes of the green entrepreneurial impacts of low-carbon policies at the metropolitan level. The potential contributions of this paper include: First, by adopting the perspective of urban green entrepreneurship effects, it delves into the net impact of low-carbon policies on urban green entrepreneurship. This not only expands the scope of research on evaluating the effectiveness of comprehensive environmental policies but also strengthens the quantitative basis for such policy assessments. Second, we explored the theoretical mechanisms through which low-carbon policies influence urban green entrepreneurship. We examined the mediating roles of green innovation stimulation effects and green consumption driving effects in the impact of low-carbon policies on urban green entrepreneurship. Further distinguishing between urban location and green finance levels can help examine how low-carbon policies promote green entrepreneurship in cities. These explorations and tests provide theoretical support for implementing low-carbon policies and fostering urban entrepreneurship, while also offering guidance for governments to develop targeted carbon reduction measures.

2 Theoretical analysis and research hypotheses

2.1 Policy background

Low-carbon policies are the product of alleviating the ecosystem threat brought about by climate warming and realizing the win-win goals of green transformation and economic development (Wang et al., 2022). In response to the global deterioration of the ecological environment, China began exploring market-based environmental regulations in the early 2000s. It launched pilot emissions trading programs in 2007, with the State Council setting China's greenhouse gas emission control targets in 2009. The national carbon emissions trading system pilot project was formally initiated in 2013 (Cao, 2020), achieving a 48.4% reduction in carbon dioxide emissions per unit of GDP by 2021 compared to 2005 levels. In July 2010, the National Development and Reform Commission identified the first batch of low-carbon pilot cities including 5 provinces and 8 cities. In 2012, the list of 28 pilot provinces and cities including Beijing and Shanghai was added, and the third batch of 45 pilot cities was added in 2017.

Since the implementation of the policy on low-carbon pilot cities, the pilot cities have formulated a series of supporting policies for low-carbon development based on their own resource endowments, with detailed implementation of construction tasks mainly focusing on promoting environmental protection and energy conservation, improving green innovation in low-carbon technologies, and promoting the development of green industries. Previous studies have found that low-carbon policies have an innovation-driven effect (Wang et al., 2022; Song et al., 2022; Wu et al., 2024). At the same time, the promotion of policies has also had a positive impact on urban green entrepreneurship.

2.2 Theoretical analysis

Low-carbon policies differ from previous environmental regulations in that cities primarily establish their own carbon reduction targets based on their economic development, resource endowments, and other foundational conditions (Song et al., 2022). With the setting of segmentation targets, low-carbon policies have gradually become an important driving force for the improvement

of entrepreneurial activity. Low-carbon policies mainly effectively stimulate green entrepreneurship in cities through multiple mechanisms such as adjusting industrial structure (Cao et al., 2025), promoting knowledge spillover and optimizing the allocation of factors, so as to accelerate industrial transformation and upgrading and technological innovation, so as to improve the entrepreneurial activity of cities. As far as carbon constraints are concerned, the carbon tax mechanism will have a certain impact on the implementation of the stability strategy of venture capital investment (Yiadom et al., 2024), and can stimulate industrial technological innovation based on the purpose of emission reduction, so as to promote green entrepreneurship in cities. First, under the pressure of low-carbon targets and institutional rules, enterprises will accelerate the research and development of energy conservation and emission reduction technologies within the controllable cost and realize green innovation (Wang et al., 2021). When the research and development cost is too high, enterprises will adopt cross-industry transformation; on the other hand, due to the reduction of market access threshold of clean and environmental protection industries, and the emerging industry. Second, low-carbon policies directly alter the relative prices and flow of production factors through tools such as fiscal subsidies, tax breaks, and green credit (Schoder and Tercioglu, 2024). Low-carbon policies direct capital away from high-carbon industries and into green ones, supporting clean energy, energy efficiency upgrades, and the circular economy (Wang et al., 2022). Meanwhile, green skills training and talent recruitment policies have enhanced the quality of human capital supply, providing specialized labor support for green entrepreneurship. This resource reallocation effect not only reduces the initial costs of green ventures but also accelerates their success through economies of scale and knowledge spillovers. Finally, low-carbon policies foster the development of green demand markets through mandatory standards and public procurement policies (Kundu, 2025), opening new niche markets for entrepreneurs. The market environment changes brought about by low-carbon policies directly impact product consumption channels and green market demand. Reduced barriers to entry in the green and clean industries provide entrepreneurs with more opportunities to start businesses.

H1: Low-carbon policies can effectively increase the net increment of green enterprises and promote green entrepreneurship in cities.

Low-carbon policies can increase entrepreneurial activities through the stimulating effect of innovation, thus promoting green entrepreneurship in cities. Low-carbon policies enhance the innovation awareness and literacy of the regional labor force, enhance the innovation ability of urban enterprises, and thus enhance the urban green entrepreneurship (Cao et al., 2025). On the one hand, the Porter hypothesis suggests that environmental regulation will help companies increase their R&D spending. Pilot cities can formulate suitable innovation strategies according to their own characteristics and endowments, introduce green technologies, reduce energy consumption costs, increase investment in new clean industries, realize the development of green economy, and thus promote the improvement of urban entrepreneurial activity (Gurtu et al., 2022). Low-carbon policies can provide businesses with greater market opportunities and incentivize them to increase investment in research, development, and innovation. For instance, in the clean energy sector, governments can offer financial and technical support through investments, tax incentives, and innovation funds, encouraging companies to dedicate significant resources to R&D and thereby fostering the growth of entrepreneurial opportunities. Moreover, low-carbon policies exhibit a combinatorial nature, leveraging a mix of policy instruments to decouple urbanization from carbon emissions. This process inevitably drives technological innovation within enterprises, thereby fostering entrepreneurial activity (Huang et al., 2022; Nguyen et al., 2022). On the other hand, facing dual pressures from carbon reduction targets and policy oversight, low-carbon pilot cities have intensified the implementation of preferential policies for green innovation through continuous learning and experience accumulation. They encourage green innovation activities by offering green subsidies, targeted tax and fee reductions, and expanding financing channels (Rakatama et al., 2024; Arsenault et al., 2025).

H2: Low-carbon policies can effectively promote green entrepreneurship in cities by stimulating green innovation vitality.

Green consumption is an important way to ease environmental pressure and promote low-carbon and sustainable development (Wang et al., 2024). The stronger the consumers' willingness to consume green, the greater the likelihood that they will choose to consume green, and the more conducive to increasing demand for green production and promoting green entrepreneurship in the city (Du et al., 2020). Low-carbon policies have a positive effect on urban green entrepreneurship by affecting green consumption, which is mainly reflected in three aspects: promoting the development of green industry, guiding consumers to favor green consumption and optimizing the urban industrial structure. Firstly, the regulatory measures related to environmental protection in the low-carbon policy force enterprises to increase the production and publicity of green products (Hou et al., 2024), promote the development of green industry, and influence the public's choice of consumption of green products. Secondly, the implementation of low-carbon policies is conducive to the popularization of the concept of green consumption. More and more consumers begin to pay attention to the environmental protection attributes of products, which directly improves the market demand for green products (Wang, 2023). Ultimately, the government promotes the purchase of green products, including new energy vehicles and energy-efficient home appliances, by offering fiscal subsidies and tax incentives (Rana and Solaiman, 2023). These measures have effectively lowered consumer purchase costs, spurred the growth of the green consumer market, improved the traditional industrial structure, and created extensive market opportunities for urban green entrepreneurship.

H3: Low-carbon policies can effectively promote green entrepreneurship in cities by affecting green consumption.

3 Methodology

3.1 Model setting

Based on the above theoretical analysis, different cities exhibit varying levels of green entrepreneurship foundations due to

inherent characteristics such as history, culture, and geographic location, and also differ in the implementation of environmental policies. Furthermore, some cities, despite not participating in low-carbon pilot programs, have nonetheless adopted similar environmental policies, industrial structure upgrading measures, and entrepreneurship promotion policies to varying degrees. Therefore, the DID model is not particularly suitable. Consequently, this study employs a two-way fixed effects model (Ma et al., 2025; Zhang et al., 2025). Given the variations in low-carbon policy implementation pathways among pilot cities, the research focuses on the implementation status of low-carbon pilot cities. The interaction term between policy intensity and policy implementation time (PIT) is selected as a policy proxy variable to examine the impact of low-carbon policies on urban green entrepreneurship. The specific model as shown in Equation 1.

$$y_{it} = \alpha + \beta PIT + \gamma Control_{it} + CityFE + YearFE + \lambda_{it} \quad (1)$$

Among them, y is the explained variable urban green entrepreneurship; PIT represents the interaction item of the implementation intensity and the implementation time of the low-carbon city pilot policy; t represents the time of low-carbon policy in different regions, and the coefficient reflects the influence of the policy; Control represents the set of control variables, including population density, education level, green finance index, science and technology level and advanced industrial structure; YearFE represents the time fixed effect; CityFE represents the fixed effect of urban individuals; λ represents the random error item.

3.2 Variable selection

3.2.1 Dependent variable

The level of urban green entrepreneurship is measured by the net increment of urban green entrepreneurial enterprises. As a measure of entrepreneurial activity at the regional level, entrepreneurial activity is widely used (Bai et al., 2022). At present, there are two main criteria for measuring entrepreneurial activity in academia. One is to measure the entrepreneurial vitality by the number of new enterprises in a certain period of time. The second is to adopt the population method, taking the number of new enterprises per 100 people as the measure of urban entrepreneurial activity (Tao et al., 2020). However, low carbon policies to promote the establishment of new enterprises seems to have an impact on new enterprises, but environmental regulations will lead to the withdrawal of enterprises with backward production capacity. Therefore, the impact of low carbon policies on urban green entrepreneurship is not a simple promoting effect. Only focusing on the entry of new enterprises can not well reflect the real situation of the impact of low-carbon policies on entrepreneurship. At the same time, considering that the implementation of low-carbon policy mainly affects green entrepreneurs, this paper uses the difference between the entry and exit of green enterprises in various regions over the years to measure the net effect of urban green entrepreneurship, as the proxy variable of urban green entrepreneurship.

3.2.2 Explanatory variable

The degree of urban green entrepreneurship, as determined by the net growth in green entrepreneurial businesses inside a city, is the study's dependent variable. Entrepreneurial activity is frequently used as a measure of entrepreneurial vigor at the regional level (Qiu et al., 2021; Bai et al., 2022). There are currently two main methods used in academia to measure entrepreneurial activity: the first is determining entrepreneurial vigor by counting the number of new businesses that have been founded over a given time period. The second takes a population-based method, measuring urban entrepreneurial activity by the number of new businesses per 100 individuals (Tao et al., 2020). However, environmental restrictions can force out-of-date businesses, even while low-carbon policies seem to encourage the creation of new businesses. As a result, low-carbon policies have an effect on urban green entrepreneurship that goes beyond promotion. The full effect of low-carbon measures on entrepreneurship is not sufficiently reflected by concentrating only on new business entry. Additionally, since green entrepreneurial businesses are the primary beneficiaries of low-carbon policy implementation, this analysis uses the net effect of green firm entry minus exit across regions over time as a proxy variable for urban green entrepreneurship.

3.2.3 Control variables

3.2.3.1 Level of urbanization (the extent of urbanization)

The degree of urbanization affects how people and resources are distributed geographically, creating an atmosphere that is conducive to urban green entrepreneurship. The population density logarithm is used because it accurately captures the dynamic shifts in the degree of urbanization (Tao et al., 2020).

3.2.3.2 Education level (edu)

Regions with high level of science and education can train highly skilled talents, which is conducive to promoting green entrepreneurship in cities. This paper adopts the ratio of the education expenditure to the government general budget expenditure to express the education level.

3.2.3.3 Green finance index

Green finance provides essential financial support and market incentives for green entrepreneurship, effectively driving its development. It primarily encompasses green credit, green insurance, and green investment (Lv et al., 2021). This paper employs the entropy method to calculate a comprehensive green finance index, measuring the development level of green finance.

3.2.3.4 Technology level (tec)

As a key tool and means of green development, science and technology can promote sustainable development, reduce environmental pollution, and provide support for green entrepreneurship. This paper uses the ratio of science and technology expenditure and government general budget expenditure to express the level of science and technology.

3.2.3.5 Industrial structure

Differences in industrial structure among cities fundamentally reflect variations in resource endowments and input factors across

urban areas. Such disparities may lead to significant variations in the difficulty and choice of entrepreneurial paths, thereby influencing urban entrepreneurial activities (Bai et al., 2022). This paper employs an industrial structure upgrading index to measure changes in regional industrial structures.

3.2.4 Mediating variable

Low-carbon pilot cities influence pollution control costs through subsidies and carbon trading mechanisms, thereby promoting urban green entrepreneurship. This study employs the number of green patent applications per 10,000 residents in prefecture-level cities as an intermediate variable to validate the impact of innovation incentives on urban green entrepreneurship. Green patent applications encompass three categories: green invention patents, green utility model patents, and green design patents. Green patents provide a direct reflection of a city's green innovation output, offering advantages such as strong quantifiability and ease of acquisition. This metric enables timely assessment of how pilot policies drive urban green innovation.

Low-carbon pilot cities influence consumers' green awareness through consumption subsidies and ethical constraints, boosting demand for green products and thereby driving urban green entrepreneurship. Therefore, selecting green consumption as an intermediary variable, this paper employs web scraping technology to extract relevant keywords from Baidu Index based on the classification standards for green products established by China's National Development and Reform Commission (covering seven major categories: new energy, shared mobility, energy-saving, water-saving, health, environmental protection, organic, green building materials, and recycled products, plus seven categories of paper products). By integrating Baidu Index data on green products, it quantifies public green consumption behavior.

3.3 Data source

This study selected 286 prefecture-level cities as its sample, with data spanning from 2007 to 2022. Net increment data for urban green entrepreneurship originated from the China Public Policy and Green Development Database. Implementation timelines for low-carbon policies were manually compiled based on relevant documents issued by the National Development and Reform Commission. Low-carbon policy intensity data was sourced from the China Low-Carbon Policy Intensity Dataset released by Wang Can's research team (Dong et al., 2024). Additional data were sourced from the Statistical Yearbook of Chinese Cities and the Statistical Yearbook of Regional Economy in China. The research sample comprised 286 prefecture-level cities in China, including 124 low-carbon pilot cities and 162 non-pilot cities. Descriptive statistics for the variables are shown in Table 1.

4 Results

4.1 Benchmark regression

Column (1) in Table 2 shows the impact of low-carbon policies on urban green entrepreneurship without the control of other variables. The regression results indicate that low-carbon policies have a significant effect on promoting urban green entrepreneurship. Columns (2) ~ (4) are the results of the addition of urban fixed effects, time fixed effects, and control variables. It can be seen that the impact of low-carbon policies on urban green entrepreneurship is still significantly positive, low carbon policies can significantly promote urban green entrepreneurship, and the greater the implementation intensity of urban low carbon policies, the greater the net increment of urban green start-ups. The results not only verify the effectiveness of low-carbon policy as a new policy tool in promoting urban entrepreneurship but also provide empirical support for policymakers, indicating that continuing low-carbon policy can help to stimulate green innovation capacity, promote the green and low-carbon transformation of various industries, and thus improve green entrepreneurship in cities.

From column (4) of Table 2, we can see the influence of each control variable on urban green entrepreneurship. The empirical results show that population density, education level, green finance

TABLE 1 Descricriptive statistics of the variables.

Variable name	Variable symbol	N	Mean	SD	Min	Max
Urban green entrepreneurship	*UGE*	4,576	0.4106	0.8157	−0.0010	25.955
Low-carbon policy intensity and time interaction term	*PIT*	4,576	19.6495	38.1062	0.0000	195.25
Density of population	*PDE*	4,576	5.7267	0.9300	1.6094	7.9054
Educational level	*EDU*	4,576	0.1798	0.0419	0.0177	0.3774
Green finance index	*LJ*	4,576	0.3185	0.1075	0.0576	0.6575
Scientific and technological level	*TEC*	4,576	0.0162	0.0164	0.0005	0.2068
Advanced industrial structure	*TS*	4,576	1.0149	0.5800	0.0943	5.6503
Green patent as a whole	*Inno*	4,576	0.9537	2.2777	0.0000	35.4066
Green invention patent	*Inno1*	4,576	0.4262	1.1529	0.0000	18.7077
Green utility model patent	*Inno2*	4,576	0.5275	1.1898	0.0000	18.5431
Green consumption willingness index	*GCI*	4,576	9.9253	13.8679	0	203.8008

TABLE 2 Baseline regression results.

Variable	(1)	(2)	(3)	(4)
	UGE			
PIT	0.0037***	0.0023***	0.0011***	0.0009**
	(11.9009)	(5.3730)	(2.7080)	(2.4535)
PDE				1.5872***
				(3.9800)
EDU				2.0136***
				(3.3412)
LJ				1.5589***
				(2.7360)
TEC				8.9564***
				(3.7191)
TS				0.1250*
				(1.7046)
Constant	0.3377***	0.0968***	0.0968***	−9.9493***
	(25.2676)	(4.0806)	(4.0806)	(-4.1284)
City FE	No	Yes	Yes	Yes
Time FE	No	No	Yes	Yes
Observations	4,576	4,576	4,576	4,576
R-squared	0.0300	0.0122	0.2778	0.3212

***, ** and * are significant at the 1%, 5% and 10% levels, respectively, with t statistics in parentheses.

TABLE 3 Robustness test.

Variables	(1)	(2)	(3)	(4)	(5)
PIT		0.0500***	0.0001**	0.1823***	0.0010**
IV	8.6018***				
Controlled variable	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Constant term	1.4721	−1.3466***	−0.1847	0.3945***	−9.9393***
N	4,576	4,576	4,576	4,576	4,576
R-squared	0.0490	-	0.0716	0.3250	0.3213

***, ** and * are significant at the 1%, 5% and 10% levels, respectively.

index, science and technology level, and advanced industrial structure have all played a significant role in promoting urban green entrepreneurship. This shows that the good resource environment and market atmosphere provide sufficient space for the development of entrepreneurial activities. The advanced industrial structure provides convenience for entrepreneurs to enter and leave the market; the development of green finance provides sufficient financial support for green entrepreneurs; it also provides relatively advanced technical resources and green entrepreneurial opportunities. Investment in science and technology and education has comprehensively raised the level of human capital in the city, promoting the high concentration of urban green innovation and entrepreneurship resources and improving the overall entrepreneurial environment.

TABLE 4 Test results of green innovation stimulation mechanism.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Inno	UGE	Inno1	UGE	Inno2	UGE
PIT	0.0022***	0.0007*	0.0012***	0.0006*	0.0010***	0.0008**
	(2.8430)	(1.8089)	(2.7063)	(1.6823)	(2.7166)	(2.0479)
Inno		0.1194***				
		(4.4038)				
Inno1				0.2452***		
				(4.5656)		
Inno2						0.1831***
						(4.6256)
Constant	−42.4158*	−4.8844*	−20.9669*	−4.8073	−21.4489*	−6.0219**
	(−1.7672)	(−1.6585)	(−1.7278)	(−1.5908)	(1.7970)	(−2.1827)
Observations	4,576	4,576	4,576	4,576	4,576	4,576
R-squared	0.3568	0.3731	0.3064	0.3792	0.3631	0.3575
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Controlled variables	Yes	Yes	Yes	Yes	Yes	Yes

***, ** and * are significant at the 1%, 5% and 10% levels, respectively.

4.2 Endogeneity issues

Although other factors affecting urban green entrepreneurship, such as urbanization level, have been controlled, there may be other potential influencing factors in the model, such as "government autonomy" (IV), which was selected as the tool variable. The main reason is that "government self-sufficiency" plays an important role in the implementation effect of low-carbon policies, meeting the correlation requirements of tool variables. Meanwhile, "government self-sufficiency" will not have a direct impact on urban green entrepreneurship and is a qualified tool variable. Table 3, column (1), reports the regression results of the instrumental variable method. The impact of low-carbon policies on urban green entrepreneurship is still significantly positive, and the conclusions obtained are still basically consistent with the previous one.

4.3 Robustness check

To further validate the robustness of the conclusion that low-carbon policies promote urban green entrepreneurship, this study replaced the explanatory variables. First, entrepreneurial vitality was measured by counting the number of newly established enterprises during a specific period. Urban population size was then used as the standardizing variable (Tao et al., 2020) to derive the urban green entrepreneurship indicator. As shown in Column (3) of Table 3, the regression results indicate that low-carbon policies still exert a significant positive impact on urban green entrepreneurship. Second, we constructed a dummy variable for low-carbon pilot city policies based on the year each city initiated such pilot programs, replacing the measurement indicator for low-carbon policies (Jiang et al., 2023). The regression results in Column (4) of Table 3 indicate that low-carbon pilot policies maintain a significant positive effect on urban green entrepreneurship, confirming the robustness of our findings. Additionally, to eliminate outliers in the control variables, we applied a two-tailed trimming procedure at the 1% percentile before regression. The results, presented in Column (5) of Table 5, show that the low-carbon pilot policy still exerts a significant positive impact on urban green entrepreneurship, indicating the robustness of our conclusions.

4.4 Mechanism analysis

Table 4, columns (1) and (3) (5), respectively, report the estimated results of the impact of low-carbon policy on green patent consolidation application, green invention patent application, and green utility model patent application, which passed the significance test at the level of 5%. This shows that low-carbon policies have significantly stimulated green innovation in cities. Further estimate the impact of green patents on urban green entrepreneurship; Table 4 first (2), (4), and (6) shows the estimated results, green patent application, green invention patent application, and green utility model patent application coefficient estimates of 0.1194, 0.2452, and 0.1831, respectively, and all at 1% through the significance test. This shows that low-carbon policies can bring about technological innovation in industries and promote the emergence of new technologies and new industries, thus promoting green entrepreneurship in cities.

Table 5, column (1), reports the estimates of the impact on green consumption of low-carbon policies. The estimated coefficient was

TABLE 5 Test results of green consumption-driven mechanism.

Variables	(1)	(2)
	GCI	UGE
PIT	0.0193***	0.0005*
	(4.8953)	(1.6777)
GCI		0.0264***
		(23.8854)
Constant	−196.9	−4.8921***
	(−13.4999)	(−4.5438)
R-squared	0.5250	0.3967
City FE	Yes	Yes
Time FE	Yes	Yes
Controlled variables	Yes	Yes

***, ** and * are significant at the 1%, 5% and 10% levels, respectively.

0.0193 and passed the significance test at the 1% level. This shows that low-carbon policies have significantly promoted green consumption. To further estimate the impact of green consumption on urban green entrepreneurship, Table 5 column (2) shows the estimation results. The coefficient estimate of green consumption is 0.0264 and has passed the significance test. This shows that low-carbon policies can change public consumption habits through policy incentives and provide good market opportunities for entrepreneurs so as to promote green entrepreneurship in cities.

4.5 Heterogeneity analysis

One important finding from the analysis of geographical heterogeneity is that there is a noticeable "southeast-northwest" divergence in the promotional effect of low-carbon pilot initiatives on green entrepreneurship (Table 6). In the northwest, the programs have little effect due to a number of structural issues, including the region's poor economic base and lack of technological resources. Tight low-carbon rules limit established high-carbon industries, but they also have a noticeable "crowding-out effect" on innovation, making it difficult to develop new green growth drivers. The southeast, on the other hand, effectively converts policy signals into market demand and technology prospects by utilizing its strong talent, money, and industrial advantages. This allows the region to fully realize the potential of green entrepreneurs. This illustrates how a region's economic growth stage and factor endowments have a significant impact on how effective low-carbon initiatives are.

The financial backing required for urban green entrepreneurship is provided by the growth of regional green financing. Developing regional green finance can, on the one hand, lower investment risks, ease financing constraints by offering various financial instruments, and encourage new businesses to enter the market. On the other hand, financial support is a practical solution to information asymmetry, which can boost businesses' capacity for innovation and, in turn, urban green entrepreneurship. Thus, the classification criteria used in this work is the average value of the comprehensive index of green finance development level across time, and the cities are classified as either high or low green finance level. Thus, with varying degrees of green finance, the diverse effects of low-carbon policies on urban green entrepreneurship are examined. The findings are displayed in Table 6's columns (3) and (4). They indicate that low carbon policies have a greater marginal impact on green entrepreneurship in areas with low green finance levels, that these areas are comparatively backward, and that there is less financial support for green entrepreneurial enterprises in these areas.

5 Discussion

5.1 Key findings

Low-carbon policies can boost the net growth of green businesses, as this study shows. This aligns with existing research,

TABLE 6 Analysis of the heterogeneity in urban green entrepreneurship.

Variables	(1)	(2)	(3)	(4)
	West of Hu Huanyong line	East of Hu Huanyong line	High-level green finance level	Low-level green finance level
PIT	0.0003	0.0010**	0.0009*	0.0008***
	(0.0006)	(0.0004)	(0.0054)	(0.0003)
Constant	−2.4083**	−11.1266***	−12.6990***	−3.9648**
	(0.9616)	(2.9966)	(2.1917)	(0.9037)
Observations	416	4,160	2,288	2,288
R-squared	0.6509	0.3229	0.2873	0.4837
City FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Controlled variables	Yes	Yes	Yes	Yes

***, ** and * are significant at the 1%, 5% and 10% levels, respectively.

which has found that environmental policies can effectively promote business development (Sun et al., 2021). The main strategy for combating global warming is the implementation of low-carbon policy. However, the effectiveness of low-carbon policies may be constrained by regional development levels, with their efficacy varying across cities (Li et al., 2024). Our findings confirm this: low-carbon policies have a stronger impact in China's southeastern regions than in the northwest. The southeastern regions exhibit higher levels of economic development, more advanced low-carbon technology adoption, and stronger infrastructure, making low-carbon technologies easier to implement. Consequently, low-carbon policies prove more effective when implemented in these areas. In contrast, underdeveloped infrastructure in the northwest limits the effectiveness of such policies. However, in regions with lower levels of green finance, the marginal incentive effect of low-carbon policies becomes more pronounced due to the inherent shortage of capital supply for green entrepreneurship.

This study, while fully considering existing scholarly research, further elaborates how low-carbon policies indirectly enhance urban green entrepreneurship by stimulating green innovation and driving green consumption. This is similar to the arguments in existing literature regarding the mediating role of green innovation in the transition to a green and low-carbon economy (Huang et al., 2022; Shobande et al., 2025). These scholars demonstrate that innovation can enhance environmental outcomes, effectively utilize environmental resources generated by low-carbon policies, and promote urban green development. Meanwhile, green consumption stimulates urban green entrepreneurship by balancing supply and demand levers.

5.2 Theoretical contributions

With a focus on the net growth in green startups, this study examines the environmental impacts of low-carbon policies from a new angle and looks at how these policies affect urban green entrepreneurship, making it practically relevant.

Start by expanding the scope of the study. The majority of existing research focuses on applying DID techniques to the execution of macro policy. However, by taking into consideration regional differences in the level of policy enforcement, this study explores the effects of low-carbon policy implementation on green entrepreneurship in greater detail. This adds to the corpus of studies that connect urban green development and low-carbon policy.

It also makes the underlying systems visible. We discovered two primary transmission channels—green innovation and green consumption—through empirical testing. This research clarifies the relationship between low-carbon policies and urban green entrepreneurship, offering a thorough theoretical foundation for future policy development.

Lastly, although though the relationship between environmental policies and green innovation has been covered in great detail in previous research (Abid et al., 2025; Amoh et al., 2025), evaluations of the heterogeneity of policy efficacy across areas can still be added. With both theoretical and empirical backing, this study further investigates the complementary function of green finance—a fundamental institutional component—in the impact of low-carbon policies on green entrepreneurship.

5.3 Policy implications

The successful execution of low-carbon policy depends on the concerted cooperation of several stakeholders, including all levels of government, urban planners, and economic decision-making organizations, given China's distinctive multi-tiered governance structure. In light of this, the study makes the following specific suggestions.

For governments, it is crucial to improve the institutional safeguards for low-carbon policies and stimulate green entrepreneurial vitality in cities. Building on established institutional structures and agreements, governments should gradually broaden the reach of low-carbon pilot projects across the country. In order to improve customized policy design for various regions, pilot policies must be applied consistently. The success of low-carbon initiatives differs from city to city due to the diversity of geographic locations and attributes. As a result, governments ought to tailor their implementation to the unique circumstances and urban character of each city, giving western regions the proper priority in order to direct more funding toward underprivileged areas.

For urban planners, providing physical space for green technologies and products is crucial. Urban planners should designate "low-carbon technology demonstration zones" to promote the adoption of green technologies, energy systems, and resource recycling facilities. Concurrently, they should prioritize the development of infrastructure for walking, cycling, and public transportation, complemented by green consumption facilities such as community-supported agriculture outlets and recycling centers. Systematic investments should be made in building comprehensive networks including electric vehicle charging stations, waste sorting and recyclable resource recovery systems, and urban ecological corridors.

For economic decision-making, providing market incentives and financial support is crucial. Work together with financial institutions to provide financial solutions aimed at green consumer markets and green technology innovation businesses. Provide tax breaks to businesses who are researching and developing important green technology. Customers who buy products with high water and energy efficiency ratings should receive direct subsidies or tax credits. In order to promote economies of scale and synergistic benefits, develop industrial plans that will direct the spatial clustering of upstream and downstream businesses in green industrial chains including photovoltaics, energy storage, and new energy vehicles. Help local green brands promote themselves in the marketplace.

5.4 Limitations and future research

5.4.1 Limitations

There are still a number of limitations even if this study suggests some of the fundamental mechanisms by which low-carbon policies

affect urban green entrepreneurship through the dual mechanisms of green invention and green consumption. First, the two main routes of green innovation and green consumption are the main emphasis of the research when it comes to mechanism identification. In practice, though, policy effects could also show up through other important avenues, such the upgrading and optimization of industrial structures or the diffusion of green technologies brought about by foreign investment. These mechanisms might lead to an insufficient knowledge of the effects of policy because they were not included in the analysis. Second, at the measurement and data level, key variables such as green consumption and green entrepreneurship mostly depend on publicly accessible macro or firm-level data. Because of this, it is challenging to completely understand the behavioral motives and decision-making processes of micro-level individuals, such consumers and entrepreneurs. Finally, it should be noted that pandemic control measures such as lockdowns may have caused temporary disruptions to our data, particularly during the 2020–2021 period. Existing research has highlighted the brief yet significant decline in CO_2 emissions observed both in China and globally during the pandemic (Le Quéré et al., 2020). This paper does not further distinguish between the interplay of such pandemic-driven "passive emission reductions" and "policy-driven low-carbon transitions," which remains a meaningful topic for future research.

5.4.2 Future research

There are various areas where future research can be expanded. Start by deepening and expanding mechanism studies. More detailed micro-level survey data, such as surveys directed at consumers and business owners, could be used in future research to directly analyze changes in their attitudes, behaviors, and perceptions regarding low-carbon policy. This would give the mechanisms of "green innovation" and "green consumption" stronger behavioral proof at the micro level. Second, it is possible to expand and improve mechanism analysis. Although the existence of core processes is shown by this study, their efficacy may differ greatly based on enterprise kinds (e.g., labor-intensive vs. technology-intensive) or city features (e.g., resource endowments, industrial foundations). In order to thoroughly examine these boundary conditions and identify the "optimal scenarios" for policy success, future study could take a configurational approach. Furthermore, it would be very beneficial to use dynamic panel models to monitor the interdependent development of green entrepreneurship and low-carbon policy across longer time series. Finally, as this study covers the period from 2007 to 2022, which includes the COVID-19 era, the lockdown measures implemented during the early stages of the pandemic caused a sharp decline in industrial activity, leading to a short-term decrease in carbon emissions (Chen et al., 2020; Liu et al., 2020). The long-term impact of post-pandemic economic recovery on low-carbon transformation also warrants attention (Lahcen et al., 2020; Lu et al., 2024). Future research may thus focus on post-pandemic carbon emission trends in China (Ahmed and Stern, 2023; Guo et al., 2023) and the evolution of low-carbon policies in response to these trends. Further exploration should examine the spatial spillover effects of low-carbon policies on urban green economic development (Liu et al., 2024; Liang and Qiao, 2025).

6 Conclusion

Building upon an analysis of policy contexts and theoretical mechanisms, this study employs panel data from 286 Chinese cities spanning 2007–2022. Using low-carbon pilot policies as an entry point, it introduces an interaction term between the intensity of low-carbon policy implementation and the timing of low-carbon pilot policy implementation. The research examines the impact and heterogeneity of low-carbon policies on urban green entrepreneurship. Furthermore, by applying a mediation effect model, it systematically tests the operational mechanisms through which low-carbon policies influence urban green entrepreneurship. The findings reveal the following: First, low-carbon policies significantly promote urban green entrepreneurship, and this conclusion remains robust after a series of stability tests. As the intensity of low-carbon policy implementation increases, a clear growth effect on urban green entrepreneurship emerges. Second, mechanism tests reveal that low-carbon policies primarily stimulate urban green entrepreneurship through two channels: green innovation incentives and green consumption drivers. Finally, heterogeneity analysis indicates that low-carbon policies significantly promote green entrepreneurial activities in cities located in southeastern China and in cities with lower levels of green finance.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

HZ: Conceptualization, Formal Analysis, Methodology, Writing – review and editing. WX: Data curation, Software, Writing – original draft, Writing – review and editing.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Acknowledgements

We would like to thank all members of the Doctoral Program in Collaborative Innovation Center of Modern Grain Circulation and Safety, and all support from the Nanjing University of Finance and Economics for making it possible to carry out this work.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abid, N., Aftab, J., and Javed, A. (2025). The impact of green technological innovation and environmental policy on ecological sustainability: evidence from leading economies. *Lett. Spat. Resour. Sci.* 18, 14. doi:10.1007/s12076-025-00405-2

Ahmed, K., and Stern, D. I. (2023). China's carbon emissions trend after the pandemic. *Environ. Challenges* 13, 100787. doi:10.1016/j.envc.2023.100787

Amin, S. (2025). Decarbonisation of road transportation in India-A round-robin review on low-carbon strategies and financial policies. *Future Transp.* 5, 36. doi:10.3390/futuretransp5020036

Amoh, J. K., Mohammed, A.-A. B., and Dziwornu, R. (2025). Mediating role of green innovation in the environmental taxation and corporate environmental responsibility nexus in an emerging economy. *Int. J. Ethics Syst.*, 1–21. doi:10.1108/IJOES-01-2025-0040

Arsenault, C., Deberdt, R., and Le Billon, P. (2025). Onshoring low-carbon supply chains: can subsidies meet the challenge? *Earth Syst. Gov.* 26, 100286. doi:10.1016/j.esg.2025.100286

Bai, J., Zhang, Y., and Bian, Y. (2022). Does the innovation-driven policy enhance urban entrepreneurial vitality? Empirical evidence from the national innovative city pilot policy. *China Ind. Econ.* 4 (06), 61–78. doi:10.19581/j.cnki.ciejournal.2022.06.016

Bu, W., Li, C., and Liu, S. (2024). Environmental regulation, R&D subsidies, and industrial green total factor productivity. *Sustain. Futur.* 8, 100333. doi:10.1016/j.sftr.2024.100333

Cao, M. (2020). A case study on China's carbon emission trading system: experiences and recommendations. *Asia Pac. J. Environ. Law* 23, 106–135. doi:10.4337/apjel.2020.02.01

Cao, X., Zhong, F., and Du, M. (2025). Can climate policy promote urban green technology innovation in China? - evidence from China's low-carbon pilot initiatives. *Sustain. Futur.* 10, 100939. doi:10.1016/j.sftr.2025.100939

Carchano, M., Cardebat, J.-M., Gonzalez, A., and Carrasco, I. (2024). Moving toward environmental sustainability through green entrepreneurship: assessing the moderating role of managerial environmental commitment. *Int. Entrep. Manag.* 20, 2209–2240. doi:10.1007/s11365-024-00995-1

Chen, K., Wang, M., Huang, C., Kinney, P. L., and Anastas, P. T. (2020). Air pollution reduction and mortality benefit during the COVID-19 outbreak in China. *Lancet Planet. Health* 4, e210–e212. doi:10.1016/S2542-5196(20)30107-8

Cheshmehzangi, A. (2021). Low carbon transition at the township level: feasibility study of environmental pollutants and sustainable energy planning. *Int. J. Sustain. Energy* 40, 670–696. doi:10.1080/14786451.2020.1860042

Cojoianu, T. F., Clark, G. L., Hoepner, A. G. F., Veneri, P., and Wójcik, D. (2020). Entrepreneurs for a low carbon world: How environmental knowledge and policy shape the creation and financing of green start-ups. *Res. Policy* 49, 103988. doi:10.1016/j.respol.2020.103988

Dong, X., Wang, C., Zhang, F., Zhang, H., and Xia, C. (2024). China's low-carbon policy intensity dataset from national- to prefecture-level over 2007–2022. *Sci. Data* 11, 213. doi:10.1038/s41597-024-03033-5

Du, L., Feng, Y., Lu, W., Kong, L., and Yang, Z. (2020). Evolutionary game analysis of stakeholders' decision-making behaviours in construction and demolition waste management. *Environ. Impact Assess. Rev.* 84, 106408. doi:10.1016/j.eiar.2020.106408

Guo, L., Bai, L., Liu, Y., Yang, Y., and Guo, X. (2023). Research on the impact of COVID-19 on the spatiotemporal distribution of carbon dioxide emissions in China. *Heliyon* 9, e13963. doi:10.1016/j.heliyon.2023.e13963

Gurtu, A., Vyas, V., and Gurtu, A. (2022). Emissions reduction policies and their effects on economy. *J. Risk Financ. Manag.* 15, 404. doi:10.3390/jrfm15090404

Hassan, S., Chen, S., Azam, A. H. M., and Olaleye, B. R. (2025). Measuring green economic growth in eastern China: influencing factors and policy perspectives. *Discov. Sustain.* 6, 700. doi:10.1007/s43621-025-01585-z

Hou, R., Qi, Z., and Wang, J. (2024). Opportunities and challenges for the mechanical industry in response to carbon peaking and carbon neutrality. *Chin. Sci. Bull.-Chin.* 69, 997–1004. doi:10.1360/TB-2023-0602

Hua, W., Li, D., Sun, H., and Matthews, P. (2020). Stackelberg game-theoretic model for low carbon energy market scheduling. *IET Smart Grid* 3, 31–41. doi:10.1049/iet-stg.2018.0109

Huang, X., Huang, P., and Huang, T. (2022). Relationship between low-carbon service innovation and enterprise performance under the background of green entrepreneurship. *Int. J. Environ. Technol. Manag.* 25, 544–563. doi:10.1504/ijetm.2022.10050682

Jiang, Xu, Hou, J., and Lu, X. (2023). The impact of low-carbon pilot policies on urban land green utilization: an empirical study based on the difference-in-differences model. *China Land Sci.* 37 (03), 80–89.

Kundu, S. (2025). Pricing and carbon emission reduction decisions in the dual-channel supply chain with exchange offers. *Opsearch*. doi:10.1007/s12597-025-01008-7

Lahcen, B., Brusselaers, J., Vrancken, K., Dams, Y., Da Silva Paes, C., Eyckmans, J., et al. (2020). Green recovery policies for the COVID-19 crisis: modelling the impact on the economy and greenhouse gas emissions. *Environ. Resour. Econ.* 76, 731–750. doi:10.1007/s10640-020-00454-9

Le Quéré, C., Jackson, R. B., Jones, M. W., Smith, A. J. P., Abernethy, S., Andrew, R. M., et al. (2020). Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. *Nat. Clim. Chang.* 10, 647–653. doi:10.1038/s41558-020-0797-x

Li, X., Xu, Y., Tan, H., and Lei, Y. (2024). Low-carbon city pilot policies and urban carbon productivity improvement: an empirical analysis from the perspective of green competitiveness. *Environ. Sustain. Indic.* 24, 100531. doi:10.1016/j.indic.2024.100531

Li, C., Bu, W., and Liu, S. (2025). The synergistic impact of green credit policy and government subsidies on green innovation of heavily polluting firms. *Discov. Sustain* 6, 1080. doi:10.1007/s43621-025-01969-1

Liang, J., and Qiao, C. (2025). The impact of digital economy on urban green and low-carbon development: mechanism and spatial spillover effect. *Front. Sustain. Cities* 7, 1591826. doi:10.3389/frsc.2025.1591826

Liu, Z., Ciais, P., Deng, Z., Lei, R., Davis, S. J., Feng, S., et al. (2020). Near-real-time monitoring of global CO2 emissions reveals the effects of the COVID-19 pandemic. *Nat. Commun.* 11, 1–12. doi:10.1038/s41467-020-18922-7

Liu, X., He, Z., Deng, Z., and Poddar, S. (2024). Analysis of spatiotemporal disparities and spatial spillover effect of a low-carbon economy in Chinese provinces under green technology innovation. *Sustainability* 16, 9434. doi:10.3390/su16219434

Lu, C., Huang, Y., Yu, Y., Hu, J., Mo, H., Li, Y., et al. (2024). Health co-benefits of post-COVID-19 low-carbon recovery in Chinese cities. *Nat. Cities* 1, 695–705. doi:10.1038/s44284-024-00115-8

Lv, C., Bian, B., Lee, C.-C., and He, Z. (2021). Regional gap and the trend of green finance development in China. *Energy Econ.* 102, 105476. doi:10.1016/j.eneco.2021.105476

Ma, H., Wang, K., and Fang, C. (2025). How does new-type urbanization promote green development efficiency in China? The mediating role of governments, enterprises, and residents. *Geogr. Sustain.* 6, 100241. doi:10.1016/j.geosus.2024.10.001

Mehmood, S., Zaman, K., Khan, S., Ali, Z., and Khan, H. ur R. (2024). The role of green industrial transformation in mitigating carbon emissions: exploring the channels

of technological innovation and environmental. *Energy Built Environ.* 5, 464–479. doi:10.1016/j.enbenv.2023.03.001

Mondal, S., Singh, S., and Gupta, H. (2025). Analyzing the indicators of green entrepreneurship for the sustainable circular economy: a mixed-method approach. *Benchmarking*. doi:10.1108/BIJ-04-2024-0356

Nguyen, C. P., Kim, S., and Su, T. D. (2022). The nonlinear relationship between entrepreneurship and natural resource rents. *J. Entrep.* 31, 632–662. doi:10.1177/09713557221136376

Qiu, S., Wang, Z., and Liu, S. (2021). The policy outcomes of low-carbon city construction on urban green development: evidence from a quasi-natural experiment conducted in China. *Sustain. Cities Soc.* 66, 102699. doi:10.1016/j.scs.2020.102699

Raihan, A., Muhtasim, D. A., Farhana, S., Pavel, M. I., Faruk, O., Rahman, M., et al. (2022). Nexus between carbon emissions, economic growth, renewable energy use, urbanization, industrialization, technological innovation, and forest area towards achieving environmental sustainability in Bangladesh. *Energy Clim. Change* 3, 100080. doi:10.1016/j.egycc.2022.100080

Rakatama, A., Maharani, D. A., Syafrian, D., and Yuniarti, F. R. (2024). Green financing for climate resilience and low-carbon development in Indonesia: viewpoints for the road ahead. *Dev. Pract.* 34, 1048–1057. doi:10.1080/09614524.2023.2295790

Rana, S. M. S., and Solaiman, M. (2023). Moral identity, consumption values and green purchase behaviour. *J. Islam. Mark.* 14, 2550–2574. doi:10.1108/JIMA-01-2021-0030

Schoder, C., and Tercioglu, R. B. (2024). A climate-fiscal policy mix to achieve Türkiye's net-zero ambition under feasibility constraints. *Eur. J. Econ. Econ. J. Policy-Interv.* 21, 331–359. doi:10.4337/ejeep.2024.02.07

Seshadri, A. K., Gambhir, A., and Debnath, R. (2025). Navigating systemic risks in low-carbon energy transitions in an era of global polycrisis. *Glob. Sustain.* 8, e6. doi:10.1017/sus.2025.7

Shobande, O. A., Tiwari, A. K., and Ogbeifun, L. (2025). Repositioning green policy and green innovations for energy transition and net zero target: new evidence and policy actions. *Sustain. Futur.* 9, 100594. doi:10.1016/j.sftr.2025.100594

Siregar, E. S., Sentosa, S. U., and Satrianto, A. (2024). Capital formation and production of carbon emissions in low-carbon development. *Glob. J. Environ. Sci. Manag.* 10, 759–772. doi:10.22035/gjesm.2024.02.21

Song, Y., Chen, X., Li, Z., Zeng, Z., and Zhang, M. (2022). Exploring the effect of a low-carbon city pilot policies on carbon dioxide emission intensity:based on the PSM-DID method. *Chin. J. Popul. Resour. Environ.* 20, 209–216. doi:10.1016/j.cjpre.2022.09.001

Sun, B., Li, H., and Li, X. (2021). Can environmental regulations achieve both profitability and profit quality? A natural experiment based on the China cleaner production standards. *Chin. J. Popul. Resour. Environ.* 19, 65–81. doi:10.1016/j.cjpre.2021.05.007

Tao, Z., Zhang, Z., and Shangkun, L. (2020). Digital economy, entrepreneurial activity, and high-quality development: empirical evidence from Chinese cities. *Manag. World* 36 (10), 65–76. doi:10.19744/j.cnki.11-1235/f.2020.0154

Wang, X. (2023). The effect of green values on green consumption behaviour. *Int. J. Educ. Inf. Technol.* 17, 32–37. doi:10.46300/9109.2023.17.4

Wang, Y., Guo, C., Chen, X., Jia, L., Guo, X., Chen, R., et al. (2021). Carbon peak and carbon neutrality in China: goals, implementation path and prospects. *China Geol.* 4, 720–746. doi:10.31035/cg2021083

Wang, C., Lin, K., and Liu, X. (2022). Can the low-carbon city pilot policy promote the upgrading of high-carbon emitting enterprises? Evidence from China. *Chin. J. Popul. Resour. Environ.* 20, 217–226. doi:10.1016/j.cjpre.2022.09.002

Wang, D., Yu, Z., Liu, H., Cai, X., and Zhang, Z. (2024). Green consumption, environmental regulation and carbon emissions—an empirical study based on a PVAR model. *Sustainability* 16, 1024. doi:10.3390/su16031024

Wu, L., Qi, L., Lam, J. F. I., and Chen, G. (2024). Climate policy and corporate artificial intelligence: evidence from low-carbon city pilots in China. *Environ. Sustain. Indic.* 23, 100446. doi:10.1016/j.indic.2024.100446

Xu, X., Hou, P., and Liu, Y. (2022). The impact of heterogeneous environmental regulations on the technology innovation of urban green energy: a study based on the panel threshold model. *Green Financ.* 4, 115–136. doi:10.3934/GF.2022006

Yiadom, E. B., Mensah, L., Bokpin, G. A., and Mawutor, J. K. M. (2024). Carbon tax adoption and foreign direct investment: evidence from Africa. *Cogent Econ. Financ.* 12, 2312783. doi:10.1080/23322039.2024.2312783

Zhang, Z. (2022). Part on green and low-carbon development of China's environmental code system response and institution implementation in sustainable development. *Front. Law China* 17, 267–287. doi:10.3868/s050-011-022-0034-8

Zhang, Y., Miao, Z., and Sun, Y. (2025). Impact of green and low-carbon technological innovation on green total factor productivity of industrial sector: an analysis based on BAM-DEA model. *Sustain. Futur.* 10, 101036. doi:10.1016/j.sftr.2025.101036