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Research on the Impact of Environmental Protection Tax on the Efficiency of Urban Green Development ——A Quasi-Natural Experiment Implemented Based on the Environmental Protection Tax Law

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Abstract: This study employs a quasi-natural experiment framework based on the policy shock of the 2018 Environmental Protection Tax Law implementation. Utilising panel data from 280 prefecture-level cities in China spanning 2010–2022, it comprehensively applies methods including the Difference-in-Differences (DID) approach and spatial econometric models to examine the policy effects of environmental protection tax on urban green development efficiency. Empirical findings indicate that the environmental protection tax significantly enhances urban green development efficiency, with this conclusion remaining robust after parallel trend tests and other stability checks. Mechanism analysis reveals that industrial structure upgrading serves as a key mediating pathway, while public environmental awareness exerts a positive moderating effect on policy outcomes. Spatial econometric results confirm that the environmental protection tax positively influences green development efficiency both locally and in neighbouring cities. The study offers insights for refining environmental taxation policies and promoting regional green coordination: synergies between industrial structure and public participation should be strengthened; differentiated policies should be implemented according to varying urban foundations; and regional linkage strategies should be formulated while accounting for spatial spillover effects.

Keywords: Environmental Protection Tax; The Efficiency of Urban Green Development; Difference-in-Differences; Spatial Metrology

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1.Introduction

For a long time, China's extensive economic growth model relied heavily on substantial resource inputs and energy consumption. The expansion of high-pollution, energy-intensive industries led to the persistent deterioration of the ecological environment, with frequent smog episodes and water pollution emerging as prominent obstacles to sustainable economic development. Green development represents a significant theoretical innovation and practical achievement forged by China in addressing ecological and environmental challenges[1]. Its essence lies in reconciling economic growth with environmental protection by establishing a new development paradigm where the economy, environment, and society coexist in synergy. This approach achieves the organic unity of economic expansion, ecological restoration, and social stability. Consequently, China has established the concept of green development as the core guiding principle for socio-economic advancement in the new era. It has defined the ‘coordinated promotion of carbon reduction, pollution control, ecological expansion, and economic growth’ as its developmental strategy for this era, explicitly advocating for ‘advancing ecological priority, resource conservation, intensive use, and green, low-carbon development.’ This underscores the pivotal role of green development within the broader framework of modernisation. Enhancing the efficiency of green development represents the core pathway to resolving the tension between environmental protection and economic growth, thereby achieving high-quality development.

Taxation, as an economic instrument of state macro-regulation, plays a vital role in advancing environmental protection and achieving green development. To effectively address environmental challenges, China enacted the Environmental Protection Tax Law in 2016, which formally came into effect in 2018. As a milestone in China's journey towards environmental governance through the rule of law, this green tax legislation employs fiscal leverage to internalise environmental costs. Through a differentiated taxation mechanism – levying higher taxes on greater pollution and lower taxes on reduced pollution – it compels enterprises to innovate production methods and reduce emissions. Amidst the accelerated pursuit of the dual carbon goals, delving into the Environmental Protection Tax Law's impact mechanisms on urban green development efficiency and analysing its implementation outcomes across cities with varying regional and economic foundations not only advances the theoretical framework of environmental policy research but also provides crucial practical guidance for refining environmental governance strategies and fostering coordinated economic and ecological development.

2.Literature Review

Academic research has yielded substantial findings regarding the policy effects of environmental protection taxation. At the micro-enterprise level, studies indicate that the implementation of the Environmental Protection Tax Law has significantly increased environmental governance investments by heavily polluting enterprises[2], stimulated corporate motivation for green technological innovation[3], and propelled the green transformation of heavily polluting enterprises[4].Additionally, scholars have observed that the implementation of the Environmental Protection Tax Law not only facilitates the attraction of green investors to enterprise[5], but also enhances both the quality and quantity of green technological innovation within firms[6-8], thereby exerting a positive influence on their total factor productivity[9-10]. However, alternative perspectives have been put forward, suggesting that environmental tax policies may to some extent inhibit innovation activities[11] and induce opportunistic behaviours such as ‘greenwashing’ among enterprises[12]. At the regional level, Wang W. et al.[13](2024) conducted empirical tests using prefecture-level city data, finding that the implementation of the Environmental Protection Tax Law effectively improves urban air quality. Zhou B. et al.[14](2022) further emphasised that environmental protection tax policies significantly enhance urban atmospheric environmental quality, with long-term policy effects outperforming short-term ones. Additionally, scholars have identified positive impacts of environmental protection tax policies on boosting regional green total factor productivity[15], accelerating regional green transformation[16], and promoting air pollution control alongside regional high-quality development[17].

Following the introduction of the green development concept, academia has conducted research across multiple dimensions, including its connotations, measurement, and influencing factors. Regarding conceptual content, some scholars have preliminarily elaborated on its definition, strategic value, and development mechanisms[18-20]. Loiseau E.[21](2016) further emphasised that green development constitutes an economic growth paradigm centred on efficiency optimisation, systemic harmony, and ecological sustainability, with its core objective being the establishment of synergistic relationships between economic, ecological, and social systems. Regarding measurement methodologies, scholars predominantly employ Data Envelopment Analysis (DEA) and its extended models[22-23]. Yang Yuping et al.[24](2022) employed the Super-SBM model to measure green development efficiency, though it excluded key input factors such as resource consumption; Lan Zirui[25] (2021) employed a total factor non-radial direction distance function and SBM-DEA model, comprehensively considering inputs, expected outputs, and non-expected outputs for measurement; Jing Jianzhuang et al.[26](2024) further utilised the SBM-GML model and exploratory spatial data analysis model to calculate green development efficiency; Additionally, Fu J.[27](2022) measured urban green development efficiency using a three-stage DEA model, though the sample was limited to selected prefecture-level cities in Liaoning and Jiangsu provinces; Liu X.[28](2023) combined super-efficiency SBM-DEA with ESDA modelling to assess and evaluate industrial green development efficiency.Regarding influencing factors, existing scholarly research has identified that digital finance[29], urbanisation[30], regional market integration[31], and carbon trading mechanisms[32] promote regional economic structural transformation and upgrading. These factors optimise the allocation of regional factors of production, enhance regional economic efficiency, and thereby facilitate green development. Wang W. et al.[33](2023) demonstrated that the ‘Made in China 2025’ pilot policy enhances urban green development efficiency through mechanisms such as technological advancement. Zhu B. et al.[34](2019) found that industrial structure promotes green development efficiency, with structural optimisation exerting a greater impact than rationalisation. Yang X. et al.[35](2022) developed a spatial Durbin model based on the STIRPAT framework, revealing that financial agglomeration exhibits a pronounced non-linear effect on neighbouring regions' green development efficiency. Li T. et al.[36](2024) observed that the promotional effect of FDI quality on green development efficiency is moderated by environmental regulations, diminishing progressively as regulatory intensity increases.

In summary, existing scholarship has conducted extensive research on the policy effects of environmental protection taxes and green development efficiency. However, few studies have integrated these two concepts within a unified framework to explore the operational mechanisms and spatial effects of environmental taxes on urban green development efficiency. Consequently, the logical chain linking the Environmental Protection Tax Law to enhancing urban green development efficiency remains unconnected, leaving scope for further investigation. Consequently, this paper establishes benchmark, mediation, moderation, and spatial models after clarifying the operational mechanisms linking environmental protection tax law and green development efficiency. It comprehensively examines the direct impact, transmission pathways, and spatial characteristics of environmental protection tax policies on urban green development efficiency. The innovative value lies primarily in: 1) establishing an analytical framework linking the Environmental Protection Tax Law to urban green development efficiency, focusing on the coordinated development mechanism between economy and environment at the urban scale, thereby enriching the systematic analysis of how environmental protection taxes influence green development efficiency; 2) employing a Difference-in-Differences (DID) model and spatial econometric models to identify policy effects through a quasi-natural experiment while revealing the spatial spillover characteristics of green development efficiency, thus addressing the neglect of the spatial dimension in previous research.

3.Theoretical Analysis and Research Hypotheses

Given the public good attributes and negative externalities inherent in environmental pollution[16], market mechanisms struggle to efficiently regulate environmental resource allocation, necessitating government intervention through regulatory measures such as environmental taxation. The implementation of the Environmental Protection Tax Law enhances urban green development efficiency through a dual mechanism: firstly, its ‘polluter pays’ principle – ‘more emissions, higher taxes; fewer emissions, lower taxes; no emissions, no tax’ – internalises the external costs of pollution, increasing the economic burden of emissions on enterprises. Firms continuing high-pollution production face higher tax liabilities. When the cost of emissions exceeds the threshold for technological upgrades, this forces energy-intensive enterprises to phase out outdated production capacity. As Pigouvian tax theory indicates, environmental taxation corrects market failures by compelling enterprises to incorporate environmental costs into production decisions, thereby shifting pollution control from ‘passive compliance’ to ‘proactive emission reduction’. Concurrently, differentiated tax rates and emission reduction incentives create positive reinforcement mechanisms. According to the Porter Hypothesis, well-designed environmental regulations stimulate corporate innovation through compensation effects. Savings from environmental taxes can be redirected towards green R&D investment, fostering a virtuous cycle of ‘emission reduction – cost reduction – innovation’. Simultaneously, the legal enforceability and implementation strength of the environmental protection tax significantly surpass those of the previous pollution discharge fee system. Its long-term, stable policy signals help establish predictable innovation expectations, driving the accumulation and diffusion of green technologies, thereby enhancing the overall green development efficiency of cities[37].

In summary, the Environmental Protection Tax Law drives corporate green transformation through dual mechanisms of constraint and incentive, optimises urban resource allocation and industrial structure, and synergistically enhances both ecological environment quality and the greening of economic development, thereby influencing urban green development efficiency. Consequently, the following hypothesis is proposed:

H1: The implementation of the Environmental Protection Tax Law can enhance urban green development efficiency.

Based on Porter's hypothesis and the innovation compensation effect, the environmental protection tax primarily optimises industrial structure through three pathways: technology, consumption, and investment. On the technological front, by increasing pollution costs, the tax compels enterprises to boost investment in green technology R&D. This innovation-driven approach compensates for profit reductions caused by environmental regulations, thereby fostering green industry development and accelerating industrial upgrading. This process aligns with the reverse logic of the 'pollution refuge' hypothesis—environmental regulations no longer drive enterprises away but instead catalyse industrial advancement through technological innovation. At the consumption level, the implementation of environmental protection tax leads to price increases for polluting products. According to demand elasticity theory, consumer demand for such products declines, shifting towards green alternatives. This creates a reverse-pressure mechanism: 'greening of consumption structure – transformation of industrial supply.' At the investment level, the environmental tax elevates compliance costs for polluting industries, curbing expansion in high-energy-consuming sectors while incentivising capital flows towards low-carbon services and strategic emerging industries. This optimises industrial structure, as factor price changes guide capital towards high-efficiency sectors, accelerating industrial upgrading. Such structural advancement further reduces pollution intensity per unit output, achieving synergistic reductions in urban resource consumption and environmental pollution while enhancing green development efficiency. Moreover, the accumulation of green technologies and preference for clean factor inputs resulting from industrial upgrading will provide sustained momentum for urban green development, forming a virtuous cycle of 'policy regulation – industrial upgrading – green development'. In summary, the following hypothesis is proposed:

H2: The implementation of the Environmental Protection Tax Law enhances the efficiency of urban green development by promoting industrial upgrading.

Based on stakeholder theory and signalling theory, public environmental awareness functions as a 'policy effect amplifier' for environmental tax legislation through dual pathways: 'stakeholder collaborative oversight' and 'efficient transmission of market signals'. This positively regulates the environmental tax law's role in enhancing urban green development efficiency. Stakeholder theory posits that the public, as a significant external oversight entity, influences government policy implementation and corporate environmental conduct through their environmental demands. Elevated public environmental awareness prompts local governments to enforce environmental tax legislation more rigorously via public scrutiny and consumer choices, while simultaneously incentivising enterprises to proactively optimise production processes and increase green technology investments. This dual effect amplifies the environmental tax law's capacity to enhance green efficiency. Signalling theory further emphasises that public attention, functioning as a market signal, amplifies the policy effects of environmental protection tax legislation. This enables enterprises to perceive environmental regulatory trends more clearly, thereby accelerating the pace of green transformation. Indeed, existing research has found that environmental policy implementation yields more significant outcomes in regions with higher levels of public environmental participation[38]. In summary, we propose the following hypothesis:

Hypothesis 3: Public environmental concern exerts a positive moderating effect between environmental protection tax legislation and urban green development efficiency.

4.Research Design

4.1 Model Design

(1)Baseline regression model

This study employs the implementation of China's Environmental Protection Tax Law in 2018 as a quasi-natural experiment, utilising a Difference-in-Differences (DID) model to identify the policy effects of the environmental protection tax on urban green development efficiency. The model specification is as follows:

$$Green_{it}=\alpha_0+\alpha_1 Policy_{it}+Controls_{it}'\alpha_2+\gamma_i+\theta_t+\varepsilon_{it} \tag{1}$$

$$Policy_{it}=Treated_{it}*Time_{it} \quad (2)$$

In equation (1), i denotes the city, and t denotes the year. $Green_{it}$ denotes the level of green development efficiency for city i in year t. ; $Policy_{it}$ denotes the policy dummy variable for the Environmental Protection Tax Law $Treated_{it}$and $Time_{it}$ represents policy and time dummy variables respectively ; α_0 denotes the constant term， α_1 denotes the coefficient indicating the impact of environmental protection tax on the efficiency of urban green development. ; $Controls_{it}$'i serves as the selected control variable， γ_i 、 θ_t represents city and time fixed effects, respectively.， ε_{it} denotes the random disturbance term。

(2)Mediation Effect Model

To test Hypothesis 2 and examine the mediating role of industrial structure between environmental protection tax and urban green development efficiency, this study constructs the following mediation effect model, drawing on Jiang Ting's[39](2022) research:

$$Str_{it}=\beta_0+\beta_1 Policy_{it}+Controls_{it}'\beta_2+\gamma_i+\theta_t+\varepsilon_{it} \quad (3)$$

Among these， Str_{it} serves as the mediating variable for industrial structure level, β_1 represents the coefficient of the core explanatory variable's effect on the mediating variable. The meanings of the remaining variables remain consistent with those described earlier.

(3)Moderation Effect Model

To test Hypothesis 3 and examine the moderating effect of public environmental concern on the relationship between environmental protection tax and urban green development efficiency, this study constructs a moderation model as follows:

$$Green_{it}=\delta_0+\delta_1 Policy_{it}+\delta_2 Pec_{it}+\delta_3 Policy_{it}*Pec_{it}+X_{it}'\delta_4+\gamma_i+\theta_t+\varepsilon_{it} \quad (4)$$

Among these, Pec_{it} represents the moderating variable public environmental concern, $Policy_{it}*Pec_{it}$ denotes the interaction term between environmental protection tax and the moderating variable, while the meanings of the remaining variables remain consistent with the preceding discussion.

4.2 Variable Description

4.2.1 Dependent variable

Urban Green Development Efficiency (Green). Green development efficiency serves as a crucial indicator for measuring the coordination between regional economic growth and environmental protection, as well as sustainable development. It reflects the comprehensive and efficient utilization of resources and the ecological environment. Drawing upon Tone's[40](2002) research, this paper employs the Super-SBM model incorporating non-desirable outputs to measure green development efficiency. The specific indicators selected are as follows:

(1)Investment

In terms of capital input estimation, following the methodology of Zhang J. et al.[41](2004), fixed asset investment is estimated using the perpetual inventory method. Labor input is approximated by the number of employees at year-end. Regarding energy input measurement, drawing on the research of Shi D. et al.[42](2020), energy input is characterized by urban energy consumption derived from nighttime light data.

(2)Expected Output

To measure expected output, this study employs actual regional gross domestic product (GDP) as the indicator. To ensure data comparability, GDP data for each city is deflated using the GDP index of the corresponding province, with 2000 as the base year, to eliminate the impact of price factors.

(3)Non-expected output

This study selected the following three types of industrial pollutants as indicators for measuring undesirable outputs: industrial sulfur dioxide emissions, industrial smoke (dust) emissions, and industrial wastewater discharges.

Table 1: Urban Green Development Efficiency Indicator System

Indicator Type	Primary indicator	Secondary Indicators
Investment	Capital	Fixed Capital Stock
	Labor	Number of employees at the end of the year
	Energy	Total Energy Consumption

Indicator Type	Primary indicator	Secondary Indicators
Expected Output	Economy	Real GDP
Non-expected output	Environment	Industrial wastewater discharge volume
		Industrial SO_2 emissions
		Industrial smoke and dust emissions

4.2.2 Core explanatory variable

Environmental Protection Tax Law Pilot Policy. This study establishes policy variables based on the tax rate autonomy granted to local governments under the Environmental Protection Tax Law. According to legal provisions, provinces may independently decide whether to raise environmental protection tax rates based on environmental carrying capacity, current pollution discharge levels, and ecological development needs (with the state only setting upper and lower limits for tax rates). As of the study's analysis date, 12 provinces/regions/municipalities (including Sichuan, Hebei, and Shandong) implemented tax rate increases, while the remaining regions maintained their original pollution discharge fee standards (tax burden transfer). Consequently, prefecture-level cities within provinces that raised tax rates were designated as the treatment group (Treat=1), and regions with tax burden transfer served as the control group (Treat=0). Given the policy's formal implementation in 2018, Treated=1 was assigned for 2018 and subsequent years, while Treated=0 was assigned for prior years. An interaction term Policy (Treat×Treated) was constructed as the core explanatory variable to examine the net effect of policy implementation.

4.2.3 Mechanism Variable

Mediating variable: Industrial structure (str), measured by the share of tertiary industry value-added in GDP; Moderating variable: Public environmental concern (pea), measured using the natural logarithm of the annual average search index for “environmental pollution” and “smog” on Baidu, following the methodology of Zheng S. et al.[43](2013).

4.2.4 Control variables

To control for potential confounding factors affecting inclusive green growth and ensure the accuracy and reliability of research findings, this study introduces the following control variables based on existing literature: (1) Science and Technology Investment (sci), represented by the ratio of urban science and technology expenditure to fiscal expenditure; (2) Government Self-Sufficiency Capacity (gco), measured by the fiscal revenue-expenditure ratio; (3) Environmental regulation intensity (ER), measured by the comprehensive utilization rate of industrial solid waste in cities; (4) Information technology level (PHONE), represented by the number of mobile phone users at year-end; (5) Financial development level (FIN), measured by the ratio of year-end deposits and loans of financial institutions to GDP.

4.3 Data Source

Based on data availability, this study ultimately constructed its research sample using panel data from 280 prefecture-level cities in China spanning 2010–2022. The data primarily originated from the China Urban Statistical Yearbook, statistical bulletins of Chinese cities, DMSP nighttime light data, the EPS database, and Baidu Search Index. For the few missing data points in the sample, linear interpolation was employed to fill gaps. Table 2 reports the descriptive statistics.

Table 2: Descriptive Statistics Results

Category	Variable	Meaning	Sample Size	Mean	Standard Deviation	Minimum	Maximum
Explanatory variable	Policy	Environmental Protection Tax Law Pilot Program	3640	0.165	0.371	0	1
dependent variable	Green	Green Development Efficiency	3640	0.275	0.222	0.053	1.318
Mediating variable	Str	Industrial Structure	3640	42.403	10.165	14.36	83.87
Control variable	Pec	Public Environmental Awareness	3640	3.654	1.035	0.001	7.151

Category	Variable	Meaning	Sample Size	Mean	Standard Deviation	Minimum	Maximum
Control variables	gco	Government self-sufficiency	3640	0.452	0.221	0.056	1.541
	fina	Level of Financial Development	3640	2.538	1.226	0.588	21.3
	sci	Investment in Science and Technology	3640	0.017	0.018	0.001	0.207
	er	Environmental Regulation Intensity	3640	78.56	23.28	0.24	160.7
	phone	Level of informatization	3640	477.8	513	29	4433

5.Empirical Results Analysis

5.1 Baseline regression results

Table 3: Benchmark Regression Results

Variable	igg					
	(1)	(2)	(3)	(4)	(5)	(6)
Policy	0.026***	0.028***	0.028***	0.028***	0.028***	0.024***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
gco		-0.084***	-0.089***	-0.087***	-0.081**	-0.081**
		(0.032)	(0.033)	(0.033)	(0.033)	(0.033)
sci			0.561**	0.555**	0.581**	0.511**
			(0.241)	(0.241)	(0.244)	(0.241)
er				0.001	0.000	0.000
				(0.000)	(0.000)	(0.000)
fina					0.004	0.004
					(0.003)	(0.003)
phone						0.000**
						(0.000)
Constant	0.271***	0.308***	0.301***	0.286***	0.272***	0.243***
	(0.002)	(0.015)	(0.015)	(0.018)	(0.022)	(0.025)
Fixed time effects	Y	Y	Y	Y	Y	Y
Individual fixed effects	Y	Y	Y	Y	Y	Y
N	3640	3640	3640	3640	3640	3640
R^2	0.740	0.740	0.741	0.741	0.741	0.742

*** indicates $p < 0.01$, ** indicates $p < 0.05$, * indicates $p < 0.1$; standard errors are shown in parentheses; the same applies below.

This study employs the Difference-in-Differences (DID) method to empirically examine the policy effects of the Environmental Protection Tax Law on urban green development efficiency. As shown in Table 3, while controlling for both time and individual fixed effects, the estimated coefficient of the core explanatory variable—Environmental Protection

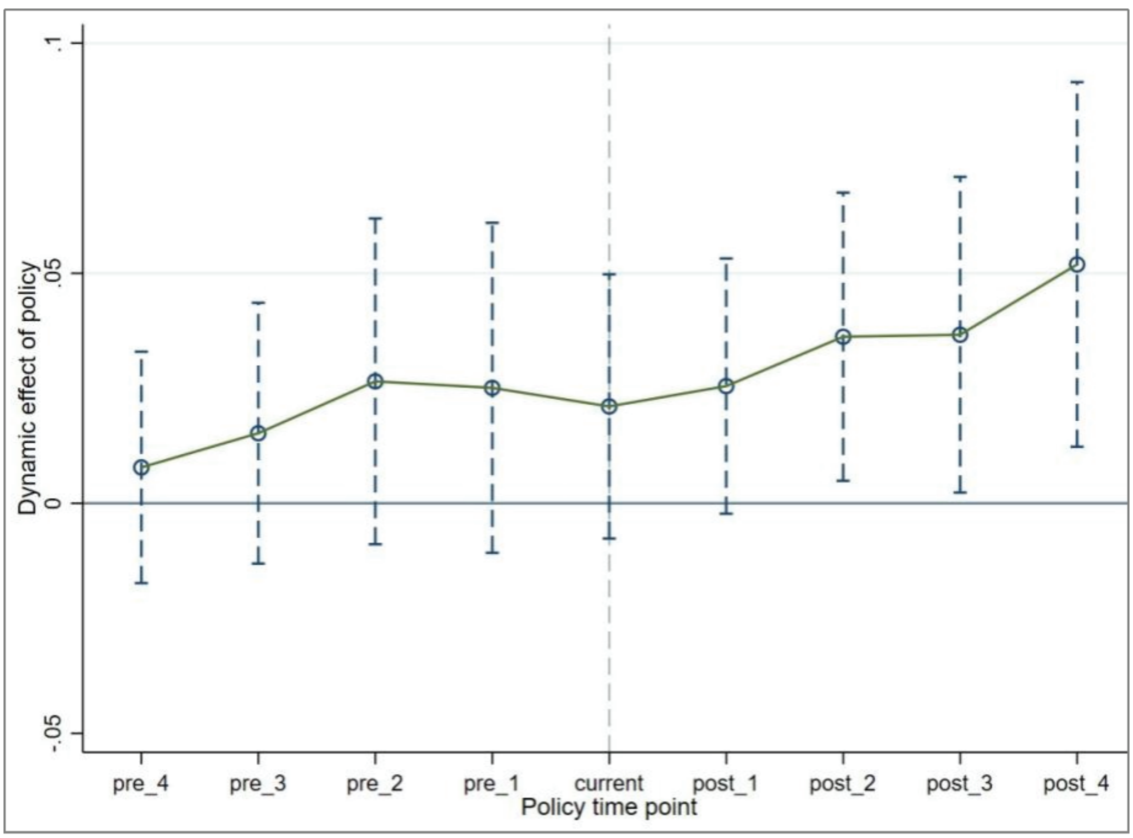
Tax (Policy)—remains positively significant regardless of whether control variables are included. This indicates that the policy implementation significantly enhances urban green development efficiency, and this result passes the robustness test of stepwise regression. The results in Column (6) of Table 3 show that after incorporating all control variables into the model, the regression coefficient for the pilot policy is 0.024 and remains significant at the 1% level. This indicates that the implementation of the environmental protection tax can effectively enhance urban green development efficiency. Hypothesis H1 is preliminarily validated.

5.2 Robustness Test

5.2.1 Parallel Trend Test

To ensure the validity of the results estimated by the difference-in-differences model, the parallel trends assumption must be satisfied, meaning that the green development efficiency of the experimental and control groups should exhibit consistent trends prior to policy implementation. To this end, this study adopts the event study method proposed by Jacobson et al.[44] (1993) to construct a parallel trends plot, as shown in Figure 1. The test results reveal that prior to policy implementation, estimated coefficients fluctuated randomly around zero and were statistically insignificant, indicating no systematic difference in green development efficiency between the experimental and control groups. Post-policy implementation, however, coefficients exhibited a significant positive jump that continued to widen. This dynamic effect validates the Environmental Protection Tax Law's role in promoting urban green development efficiency, satisfying the parallel trend assumption.

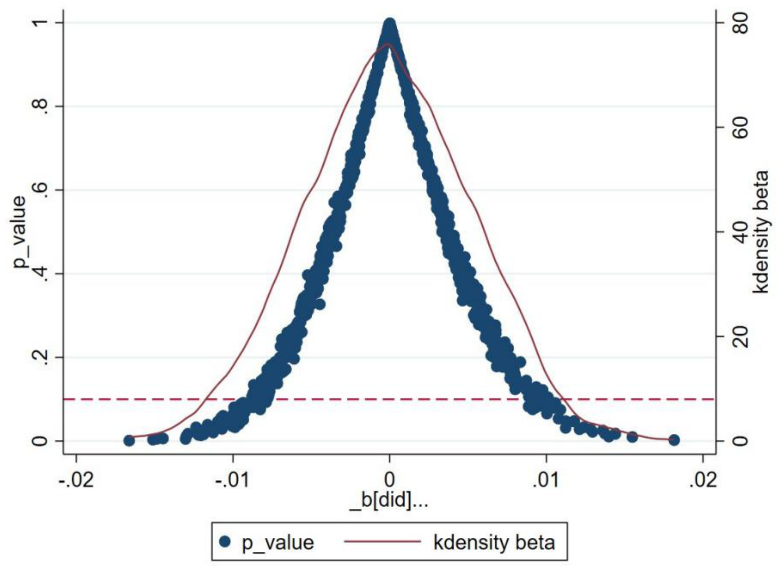
Figure 1: Parallel Trend Test



5.2.2 Placebo test

To further validate the reliability of the benchmark regression results, this study employs a placebo test method to eliminate the influence of other potential confounding factors. Specifically, by randomly generating the experimental group, 1000 simulated regressions were conducted on the sample. As shown in Figure 2, the estimated coefficients for the random treatment effect are densely clustered around zero, with the vast majority of regression results yielding P-values greater than 0.1. The coefficient for Policy in the benchmark regression (0.024) stands out as a clear outlier among the 1000 test results. These findings collectively indicate that the environmental protection tax's positive impact on urban green development efficiency remains unaffected by random factors, further validating the robustness of the estimation results.

Figure 2: Placebo Test



5.2.3 Endogeneity Test

To mitigate potential endogeneity issues in the model, this study further employs the instrumental variables approach for estimation. An effective instrumental variable must satisfy both the correlation condition and the exogeneity condition. Therefore, river density (river) is selected as the instrumental variable. Regarding correlation, stringent central government oversight of rivers means that regions with high river density face greater pollution control pressures. Local governments in these areas tend to enforce the Environmental Protection Tax Law more rigorously and are more likely to pilot environmental regulatory policies there, thus satisfying the correlation condition[45]. Regarding exogeneity, river density is a natural geographic feature that cannot directly influence urban green development efficiency, thus satisfying the exogeneity requirement for instrumental variables. The regression results for the instrumental variable are presented in Table 4. In the first-stage regression, the estimated coefficient for the instrumental variable River was 5.461, passing the 1% significance test, indicating that the instrumental variable satisfies the correlation condition. In the second-stage regression, the estimated coefficient for Policy remains significantly positive at the 1% level and passes the unidentifiability test and weak instrumental variable test. This indicates that after controlling for potential endogeneity bias, the implementation of the Environmental Protection Tax Law still significantly promotes urban green development efficiency.

Table 4: Endogeneity Test: Two-Stage Least Squares Method

Variable	2SLS estimation	
	Phase One(Policy)	**Phase Two(Green)**
	(1)	**(2)**
River	5.461*** (0.157)	
Policy		0.067*** (0.013)
Constant	-0.753*** (0.154)	0.829*** (0.135)
Control variables	Y	Y
Fixed time effects	Y	Y
Individual fixed effects	Y	Y
N	3360	3360
R^2	0.879	0.746
Kleibergen-Paap rk LM		1080.87 [0.000]
Kleibergen-Paap Wald rk F		1202.33 {16.38}

The values within [] represent p-values, while those within {} denote the critical values at the 10% significance level for the Kleibergen-Paap Wald rk F weak identification test.

5.2.4 PSM-DID Test

To address potential selection bias arising from dividing the experimental and control groups solely based on tax adjustment criteria, this study further employs Propensity Score Matching with Difference-in-Differences (PSM-DID) for validation. Using control variables as matching characteristics and leveraging kernel matching methods, the experimental and control groups are matched. Finally, the PSM-DID approach is applied to estimate the impact of the pilot policy on urban green development efficiency. The results are presented in Table 5, Column (1). The coefficient for Policy is 0.025, which is close to the DID regression result and remains significantly positive, confirming the robustness of the earlier estimation results.

5.2.5 Eliminate other policy interference

During the sample period from 2010 to 2022, other environmental regulatory policy factors existed, such as the “Broadband China” pilot program and low-carbon city pilot initiatives. To exclude the influence of these policies on regression results and explore the net effect of the environmental protection tax law pilot policy, this study incorporates the low-carbon city pilot and “Broadband China” pilot programs into consideration. Policy dummy variables are constructed for each, and a multi-period DID regression is conducted. Results in Table 5, columns (2) and (3), show that the coefficients for the core explanatory variable Policy pass the 1% significance level test, validating the robustness of the benchmark regression results.

5.2.6 Exclude municipalities directly under the central government

Given the unique characteristics of the four municipalities in terms of economic development levels, policy resource endowments, and administrative tiers, coupled with their direct relationship with the central government, they possess greater advantages in implementing and completing relevant policies. To avoid interference from their sample characteristics on the estimation results, this study conducted a regression analysis after excluding all municipal samples. The estimation results in Column (4) of Table 5 indicate that after excluding the municipality samples, the regression coefficient for the pilot policy on urban green development efficiency remains significantly positive at 0.025. This confirms the robustness of the baseline regression results.

Table 5: Robustness Test Results

Variable	PSM-DID	Eliminate other policy interference		Exclude municipalities directly under the central government
	(1)	(2)	(3)	(4)
Policy	0.025^{***}	0.024^{***}	0.024^{***}	0.025^{***}
	(0.008)	(0.009)	(0.009)	(0.009)
kuandai		-0.003		
		(0.009)		
smartcity			0.004	
			(0.011)	
Constant	0.230^{***}	0.243^{***}	0.242^{***}	0.229^{***}
	(0.0279)	(0.025)	(0.025)	(0.024)
N	3630	3640	3640	3588
Control variables	Y	Y	Y	Y
Fixed time effects	Y	Y	Y	Y
Individual fixed effects	Y	Y	Y	Y
R^2	0.742	0.742	0.742	0.741

5.3 Heterogeneity Analysis

5.3.1 Environmental Regulation Heterogeneity

To examine the heterogeneous impact of environmental regulation foundations on policy effectiveness, this study categorizes the sample into two subgroups based on China's National Environmental Protection 11th Five-Year Plan classification standards: key environmental protection cities and non-key cities. The grouped regression results in Table 6 reveal significant heterogeneity in policy effects: the Policy coefficient is significant in the non-key environmental protection city sample but not in the key environmental protection city sample. This may stem from the fact that key environmental protection cities had already accumulated a high level of environmental regulation intensity prior to policy implementation. Following the implementation of the 11th Five-Year Plan, these cities established environmental monitoring networks and implemented measures such as total pollutant emission controls, resulting in relatively well-developed environmental governance systems. Consequently, the implementation of the Environmental Protection Tax Law functioned more as a supplement to existing policies, struggling to yield significant marginal improvements. In contrast, non-environmental protection key cities had relatively lax environmental regulations and weak policy foundations in the early stages. The implementation of the Environmental Protection Tax Law introduced entirely new constraints and incentive mechanisms, effectively stimulating enterprises' green technological innovation vitality, accelerating the transformation of production methods, and thereby enhancing green development efficiency.

Table 6: Test Results for Environmental Regulation Heterogeneity

Variable	Non-key environmental protection city	Key Environmental Protection Cities
	(1)	(2)
Policy	0.028^{**}	0.001
	(0.012)	(0.014)
Constant	0.179^{***}	0.286^{***}
	(0.027)	(0.052)
Control variables	Y	Y
Fixed time effects	Y	Y
Individual fixed effects	Y	Y
N	2,223	1,417
R^2	0.655	0.795

5.3.2 Urban Hierarchical Heterogeneity

This study categorizes the sample cities into two types based on the city classification standards of China's 2022 Urban Commercial Appeal Ranking: economically developed regions (including first-tier, new first-tier, and second-tier cities) and economically underdeveloped regions (including third-, fourth-, and fifth-tier cities). The results of the grouped regression analysis in Table 7 indicate that in economically underdeveloped regions, the pilot policy significantly enhances green development efficiency. Conversely, in economically developed cities, the policy's impact fails to pass the significance test. This disparity likely stems from the fact that economically developed regions have already invested substantial resources in environmental governance, establishing relatively comprehensive environmental management systems and environmental protection technical standards. Under long-term policy constraints, enterprises in these regions have reached a relatively mature stage of green transformation. As an incremental policy, the environmental protection tax pilot program struggles to exert a significant marginal impact on green development efficiency. Conversely, in economically underdeveloped regions where environmental governance investments remain relatively insufficient and production methods are more extensive, the cost pressures imposed by the environmental protection tax can directly compel enterprises to alter their production models. By achieving cost reductions and efficiency gains through energy conservation and emission reduction, these regions experience a marked enhancement in green development efficiency.

Table 7: Test Results for Heterogeneity in Urban Hierarchy

Variable	**economically developed cities**	**economically underdeveloped cities**
	(1)	**(2)**
policy	0.017	0.020**
	(0.025)	(0.009)
Constant	0.595***	0.167***
	(0.134)	(0.024)
Control variables	Y	Y
Fixed time effects	Y	Y
Individual fixed effects	Y	Y
N	637	3,003
R^2	0.771	0.679

5.4 Analysis of Mechanism of Action

5.4.1 Mediation Analysis

Based on the preceding theoretical analysis, it is evident that the environmental protection tax may not directly enhance urban green development efficiency. Instead, it primarily promotes green development efficiency by facilitating industrial structure upgrading. To this end, this study employs Model 3 to test the mediating effect, with the results presented in Column (1) of Table 8. The regression coefficient for the environmental protection tax pilot policy on industrial structure upgrading is 1.279, which is statistically significant at the 1% level. These findings indicate that the pilot policy significantly promotes industrial structure upgrading, thereby exerting a positive effect on the measured green development efficiency. Based on the above analysis, Hypothesis 2 is supported.

Table 8: Mechanism Effect Test

Variable	**Str**	**Green**
	(1)	**(4)**
Policy	1.279***	0.019**
	(0.242)	(0.008)
Pec		0.010
		(0.006)
Policy*Pec		0.033***
		(0.009)
Constant	35.946***	0.216***
	(1.350)	(0.028)
Control variables	Y	Y
Fixed time effects	Y	Y
Individual fixed effects	Y	Y
N	3640	3640
R^2	0.901	0.744

5.4.2 Moderation Effect Analysis

To examine the moderating effect of public environmental concern on the policy effectiveness of the environmental protection tax pilot program, this study employs Model 4 for empirical analysis, with results presented in Column (2) of Table 8. Specifically, the regression coefficient for the environmental protection tax pilot program is 0.019, which is positively significant at the 5% level. The interaction term coefficient between public environmental concern and the environmental protection tax is 0.033, and it is positively significant at the 1% level. This indicates that public environmental concern can positively moderate the pilot policy's role in promoting the efficiency of green development. In summary, Hypothesis 3 is supported.

5.5 Spatial Metric Analysis

To further investigate the spatial spillover effects of pilot policies, this study constructs a spatial econometric model to test spatial effects. Spatial autocorrelation across the entire region reflects the degree of spatial interdependence in green development efficiency among cities. The global Moran's I index ranges from (-1, 1), where a positive index indicates positive spatial correlation in green development efficiency, a larger absolute value signifies deeper spatial association, and a value of 0 indicates no correlation between regions. Calculations based on the economic geographic distance nested matrix (Table 9) reveal that Moran's I indices measuring green development efficiency were significantly positive at the 1% significance level throughout the study period. This result confirms the existence of a significant positive spatial correlation in green development efficiency during the observation period, providing theoretical justification for subsequent in-depth analysis using spatial econometric models.

Table 9: Moran's I Values for Urban Green Development Efficiency

Time	Moran’sI	Z	P
2010	0.085	3.081	0.001
2011	0.089	3.220	0.001
2012	0.117	4.220	0.000
2013	0.122	4.375	0.000
2014	0.116	4.210	0.000
2015	0.102	3.694	0.000
2016	0.072	2.597	0.005
2017	0.082	2.923	0.002
2018	0.102	3.609	0.000
2019	0.139	4.901	0.000
2020	0.110	3.866	0.000
2021	0.147	5.158	0.000
2022	0.120	4.221	0.000

Second, to determine an appropriate spatial econometric model, this study follows the methodology proposed by Elhorst[46] (2014) and employs a series of tests to assess the suitability of spatial models. Based on the results of the relevant tests presented in Table 10, this study selects the fixed-effects spatial Durbin model for empirical analysis. The regression results are shown in Table 11.

Table 10: LM, Robust-LM, LR, Wald, and Huasman Test Results

Testing Methods	statistical measure	p
LM-error	6.806	0.009
LM-lag	12.210	0.000
Robust-LM-error	62.553	0.000
Robust-LM-lag	67.957	0.000
LR-error	32.93	0.000
LR-lag	31.46	0.000
Wald-SEM	31.58	0.000
Wald-SLM	33.03	0.000
Huasman	67.93	0.000

Table 11: SDM Regression Results

Variable	SDM	Direct	Indirect	Total
	(1)	(2)	(3)	(4)
W×Policy	0.051***	0.029**	0.064***	0.092***
	(0.013)	(0.008)	(0.014)	(0.013)
ρ	0.147***			
	(0.034)			
Sigma2_e	0.013***			
	(0.000)			
Control variables	Y	Y	Y	Y
Fixed time effects	Y	Y	Y	Y
Individual fixed effects	Y	Y	Y	Y
N	3640	3640	3640	3640
R^2	0.093	0.093	0.093	0.093

Column (1) of Table 11 shows that the coefficient of the spatial weighting term W×Policy is 0.051, significant at the 1% level. This indicates that the pilot policy exerts a positive influence on the green development efficiency of neighboring cities, demonstrating a positive spatial spillover effect. To comprehensively analyze the implementation effects of the pilot policy, the policy effects were further decomposed into direct effects, indirect effects (i.e., spatial effects), and total effects. The results are presented in columns (2) to (4) of Table 11. (4). The coefficient for the direct effect is 0.029, while that for the indirect effect is 0.064. This indicates that the pilot policy not only enhances green development efficiency in its own region but also positively impacts neighboring areas through spatial spillover effects.

6.Conclusions and Implications Recommendations

6.1 Conclusion

This study treats the implementation of China's Environmental Protection Tax Law in 2018 as a quasi-natural experiment, constructing a double difference model to systematically evaluate the policy's impact on urban green development efficiency and its underlying mechanisms. Empirical results indicate that the environmental protection tax policy significantly enhances urban green development efficiency. This conclusion remains robust after multiple tests, including placebo tests and PSM-DID analyses. Mechanism analysis reveals that industrial structure plays a crucial mediating role in the policy's impact on green development efficiency, while public environmental awareness exerts a positive moderating effect, significantly amplifying the policy's impact. Heterogeneity analysis indicates pronounced regional differences in the law's effects, with more pronounced impacts observed in non-environmental priority cities and economically underdeveloped cities. Spatial econometric analysis reveals significant spatial spillover effects in urban green development efficiency. The implementation of the Environmental Protection Tax Law not only substantially enhances green development efficiency within the region but also exerts positive radiating effects on surrounding cities.

6.2 Revelation suggestion

Based on the findings of this study, the following policy recommendations are proposed to enhance the role of environmental protection tax in promoting the efficiency of urban green development: 1) Refine the environmental protection tax system and deepen its reform process. Increase the tax rate standards, strengthen environmental regulations, and fully leverage the incentive potential of environmental protection tax for urban green development efficiency. Implement differentiated tax rates, fully considering regional and corporate heterogeneity, and establish tailored environmental protection tax rates based on each city's environmental carrying capacity and economic development level. 2) Strengthen the guiding role of industrial structure upgrading by actively promoting industrial restructuring and optimization. Fully leverage the environmental protection tax's role in advancing industrial transformation through supporting measures such as tax incentives and fiscal subsidies to encourage enterprises to transition toward green, low-carbon industries. Prioritize support for high-tech industries and modern service sectors while driving technological upgrades and resource consolidation in traditional high-pollution industries. 3) Enhance environmental information disclosure and public awareness campaigns. Utilize new media platforms to disseminate environmental knowledge and heighten public attention to environmental issues. Establish regular mechanisms for public participation in environmental governance, such as public oversight channels for environmental tax collection, fostering a collaborative governance framework among government, enterprises, and the public. 4) Given the spatial spillover effects of the environmental protection tax, strengthen interregional policy coordination and cooperation. Establish cross-regional environmental governance coordination mechanisms to share pollution monitoring data and technical resources, prevent pollution transfer and free-riding, and achieve coordinated green development across regions. 5) Integrate with other environmental policy tools (e.g., carbon emissions trading, green finance) to create multidimensional policy synergies. Simultaneously, enhance support for corporate green technological innovation by establishing dedicated funds to reduce transition costs for enterprises, ensuring the long-term effectiveness of environmental protection tax policies.

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Reference

[1] Huang, M., & Ye, Q. (2017). Marxist green development perspective and contemporary China's green development: A critique of the environmental-development incompatibility theory. Economic Research Journal, 2017(6), 17–30.

[2] Tian, L., Guan, X., Li, Z., et al. (2022). Environmental tax reform and corporate environmental investment: A quasi-natural experiment based on the implementation of the Environmental Protection Tax Law. Journal of Finance and Economics, 48(9), 32–46+62.

[3] Fu, M., & Xue, G. (2024). Has the environmental fee-to-tax reform enhanced corporate green innovation? Taxation and Economic Research, 29(2), 67–77.

[4] Xu, Y., & Liu, X. (2024). The impact of environmental protection tax on corporate digital transformation: A quasi-natural experiment based on the Environmental Protection Tax Law. Industrial Technology Economics, 43(4), 57–66.

[5] Liu, M., Fang, X., & Ying, W. (2025). Greening tax systems and green investor entry: Evidence from the implementation of the Environmental Protection Tax Law. Foreign Economics and Management, 47(1), 38–53.

[6] Yang, R., & Xue, H. (2024). Tax system greening and green innovation in manufacturing enterprises: A quasi-natural experiment based on the Environmental Protection Tax Law. Industrial Economics Review, (5), 149–164.

[7] Liu, B., & Liu, Z. (2024). Environmental Protection Tax Law and corporate green innovation: A chain-mediation model based on environmental legitimacy and resource acquisition. Research and Development Management, 36(4), 113–127.

[8] Guo, B. N., Feng, W. Z., Yu, Y. S., et al. (2023). Can environmental tax improve the environmental investment? Evidence from a quasi-natural experiment in China. Environmental Science and Pollution Research, 30(53), 113846–113858.

[9] Wang, J., Han, Z., & Gu, X. (2022). Environmental tax reform and total factor productivity of resource-based enterprises: A quasi-natural experiment based on the implementation of the Environmental Protection Tax Law. Journal of Beijing Technology and Business University (Social Sciences Edition), 37(6), 111–124.

[10] Sun, X. K., & Zhang, C. Y. (2023). Environmental protection tax and total factor productivity—Evidence from Chinese listed companies. Frontiers in Environmental Science, 10, 1104439.

[11] Niu, M., & Liu, Y. (2021). Can increasing pollution discharge fees promote corporate innovation?: Implications for China's environmental tax implementation. Statistical Research, 38(7), 87–99.

[12] Hu, S., Wang, A. L., & Du, K. R. (2023). Environmental tax reform and greenwashing: Evidence from Chinese listed companies. Energy Economics, 124, 106873.

[13] Wang, W., & Wang, P. (2024). Can environmental tax reform improve urban air quality? — A quasi-natural experiment based on the implementation of the Environmental Protection Tax Law of the People's Republic of China. Journal of Central South University of Forestry and Technology (Social Sciences Edition), 18(4), 30–46.

[14] Zhou, B., Yang, L., & Li, J. (2022). Has the implementation of China's Environmental Protection Tax significantly improved environmental quality? An empirical analysis based on environmental indicators at the prefecture-level city level. Taxation Research, (11), 59–65.

[15] Han, F., & Yan, S. (2023). Can the Environmental Protection Tax promote regional green total factor productivity growth? An empirical study based on Bayesian spatio-temporal statistics. Economic Issues, (7), 103–112.

[16] Yang, Y., Huang, J., & Li, H. (2024). The Environmental Protection Tax Law and regional green transformation: Mechanisms and effects. Accounting Monthly, 45(2), 102–109.

[17] Zhang, Y., & Wang, F. (2022). Study on the impact of environmental protection tax on air pollution in resource-based cities. Resources and Environment in Arid Areas, 36(6), 41–46.

[18] Zhu, D. (2020). Xi Jinping's green development philosophy: Theoretical foundations, conceptual framework, and contemporary significance. Economist, 2020(3).

[19] Hu, A., & Zhou, S. (2014). Green development: Functional definition, mechanism analysis, and development strategy. China Population, Resources and Environment, 2014(1).

[20] Huang, M., & Lin, S. (2013). Pollution damage, environmental governance, and sustainable economic growth: An analysis based on a five-department endogenous growth model. Economic Research Journal, 2013(12).

[21] Loiseau, E., Saikku, L., Antikainen, R., et al. (2016). Green economy and related concepts: An overview. Journal of Cleaner Production, 13(9), 361–371.

[22] Jiao, A., & Tao, H. (2025). Measuring the efficiency and spatiotemporal evolution of green tourism development in the Beijing-Tianjin-Hebei urban agglomeration under the “Dual Carbon” context. Ecological Economics, 41(6), 136–145.

[23] Yu, L., Zhou, T., & Gao, Y. (2023). Digital economy, green technological innovation, and urban green development efficiency: An analysis from a spatial correlation perspective. Industrial Technology Economics, 42(12), 65–73.

[24] Yang, Y., & Zou, W. (2022). Service sector opening, capital factor allocation, and green development efficiency. China Circulation Economy, (12).

[25] Lan, Z. (2021). Heterogeneous impacts of low-carbon urban development on regional green development efficiency. Modern Economic Research, (6), 101–110.

[26] Jing, J., Zhang, H., & Duan, J. (2024). Spatiotemporal differentiation and evolutionary characteristics of China's coal green development efficiency. Technology and Innovation Management, 45(4), 425–434.

[27] Fu, J. (2022). Spatial agglomeration and urban green development efficiency: An empirical analysis based on Liaoning and Jiangsu Provinces. Urban Problems, (8), 62–72.

[28] Niu, L. (2025). Research on the impact of digital finance on green development efficiency. Soft Science, 39(4), 120–126.

[29] Liu, X. (2023). Measuring China's industrial green development efficiency and its influencing factors: An analysis based on panel data from the Chengdu-Chongqing Economic Circle. Price Theory and Practice, (5), 172–175+210.

[30] Wang, G. (n.d.). Research on the impact mechanism of urbanization on urban green development efficiency: An empirical test based on spatial econometrics and mediating effect models. Journal of Dalian University of Technology (Social Sciences Edition), 1–12.

[31] Zhou, W. (2024). Does regional market integration enhance urban green development efficiency? An empirical analysis based on the Yangtze River Delta unified market. Journal of Lanzhou University, (3), 28–45.

[32] Zhu, B., Zhang, M., Huang, L., et al. (2020). Exploring the effect of carbon trading mechanism on China's green development efficiency: A novel integrated approach. Energy Economics, 85, 104601.

[33] Wang, W., Wang, J., Xie, C., et al. (2023). Impact of pilot demonstration cities for “Made in China 2025” on urban green development efficiency. China Population, Resources and Environment, 33(9), 147–158.

[34] Zhu, B., Zhang, M., Zhou, Y., et al. (2019). Exploring the effect of industrial structure adjustment on interprovincial

green development efficiency in China: A novel integrated approach. Energy Policy, 134, 110946.

[35] Yang, X., & Wu, F. (2022). Financial agglomeration, spatial spillovers, and urban green development efficiency. Wuhan Finance, (2), 79–88.

[36] Li, T., & Han, Y. (2023). The impact of FDI quality on green development efficiency from an environmental regulation perspective: A case study of three major urban agglomerations in the Yangtze River Economic Belt. International Trade and Economic Exploration, 39(2), 53–68.

[37] Zhang, T. (2017). Can strengthening environmental regulations benefit both the present and the long term? Finance and Trade Economics, (3), 116–130.

[38] Zhang, J., & Ma, Y. (2024). Climate change risks and enhancing urban resilience: A perspective on policy synergy between sponge cities and climate-adaptive cities pilot programs. Journal of Urban Studies, 45(4), 65–74.

[39] Jiang, T. (2022). Mediating and moderating effects in empirical studies of causal inference. China Industrial Economics, (5), 100–120.

[40] Tone, K. (2002). A slacks-based measure of super-efficiency in data envelopment analysis. European Journal of Operational Research, 143(1), 32–41.

[41] Zhang, J., Wu, G., & Zhang, J. (2004). Estimation of interprovincial physical capital stock in China: 1952–2000. Economic Research Journal, (10), 35–44.

[42] Shi, D., & Li, S. (2020). Pollution permit trading system and energy utilization efficiency: Measurement and empirical analysis of prefecture-level and above cities. China Industrial Economics, (9), 5–23.

[43] Zheng, S., Wan, G., Sun, W., et al. (2013). Public demands and urban environmental governance. Management World, (6), 72–84.

[44] Jacobson, L. S., LaLonde, R. J., & Sullivan, D. G. (1993). Earnings losses of displaced workers. The American Economic Review, 685–709.

[45] Yuan, Y., Xu, Q., & Gan, X. (2023). How to leverage market mechanisms to promote the synergistic development of low-carbon transformation and stable growth in manufacturing: A study based on carbon emission trading policies. Journal of Southwest University for Nationalities (Humanities and Social Sciences Edition), 44(12), 97–109.

[46] Elhorst, J. P. (2014). Matlab software for spatial panels. International Regional Science Review, 37(3), 389–405.