

Green Taxation and Green Technology Innovation in China: The Moderating Effects of Economic Context

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Abstract

This paper empirically investigates the impact of green taxation on green technology innovation at the provincial level in China, focusing on the moderating role of Chinese economic environment. The study constructs a moderating effect model for analysis, utilizing provincial panel data from 2007 to 2022. The results demonstrate that broad green taxation exerts a significantly stronger driving effect on green technology innovation compared to narrow green taxation. Social consumption level and labor force level were found to exert a negative moderating influence on the relationship between green taxation and green technology innovation. The primary conclusion underscores that establishing a comprehensive green taxation system characterized by broad coverage is crucial for effectively incentivizing green technology innovation in China. These empirically robust findings provide actionable insights for policymakers and corporate leaders.

Keywords: Green Taxation, Green Technology Innovation, Moderating Effect

Introduction

Global environmental governance is confronting unprecedented and severe challenges. As a market-based environmental policy instrument, green taxes are grounded in the principle of “Pigouvian taxes” and primarily target environmental protection. They generally refer to a collective term for various levies imposed on polluting emissions, resource consumption, or specific environmentally damaging behaviors. Green taxes establish a clear price on pollution, providing firms with a continuous financial incentive to reduce emissions until their marginal abatement cost equals the tax rate. This price signal theoretically encourages firms to choose the least-cost abatement pathways, thereby more effectively stimulating the development and diffusion of green technologies (Milliman and Prince, 1989). Although not a direct tax, the carbon pricing mechanism of the EU Emissions Trading System (EU ETS) has been found by multiple studies to promote low-carbon patenting activity (Calel and Dechezleprêtre, 2016; Borghesi et al., 2023). Nevertheless, the relationship between green taxes and green technological innovation is far from a simple linear one; its effectiveness is profoundly influenced by a multitude of complex factors.

Current progress and existing gaps in empirical research motivate this study to focus on the systematic testing of moderating effects. While abundant literature explores the impact of environmental policies on innovation, conclusions exhibit significant divergence (Rubashkina et al., 2015). Some studies support the Porter Hypothesis, finding positive effects (Dechezleprêtre and Sato, 2017; Cael et al., 2016), while others show weak, insignificant, or even negative effects (Brunnermeier and Cohen, 2003; Lanoie et al., 2011). This inconsistency largely stems from a failure to adequately incorporate key moderate variables. Although an increasing number of studies have recently begun to focus on heterogeneity (Albrizio et al., 2017), research systematically integrating multi-level moderating factors specifically for green taxes remains relatively scarce. China offers a unique setting for testing moderating effects due to its vast regional disparities in economic development stages, industrial structure, institutional environment, financial deepening, and uneven distribution of foreign investment inflows. However, existing China-focused studies primarily concentrate on single moderating factors (Hering and Poncet, 2014), lacking systematic and nuanced empirical tests of how green taxes interact with multi-level moderators. Globally, studies utilizing a unified framework to simultaneously analyze multi-dimensional moderating effects are also uncommon (Popp, 2019).

Therefore, to address these research gaps, this study employs rigorous theoretical frameworks and econometric methods, integrating the principles of Pigouvian taxation and the Porter Hypothesis, to specifically investigate the moderating role of Chinese economic environment in the transmission mechanism from green taxes to green technological innovation. The innovations of this research lie in the following aspects: First, at the theoretical level, it is the first to systematically validate and quantify the significant disparity in the innovation incentive effects between the scope of green tax levies within the context of a major developing economy. This advances beyond studies focused on the impact of single environmental tax types or regulatory stringency (Rubashkina et al., 2015), providing more granular support for the Porter Hypothesis concerning tax system design dimensions (Porter and van der Linde, 1995) and offering strong empirical resonance with theoretical advocacy for carbon tax design principles (Metcalf, 2019). Second, regarding moderating mechanisms, this study innovatively reveals and explains the significant negative moderating effects of social consumption levels and labor force levels on the innovation effect of green taxes. The negative moderation by social consumption level challenges the simplistic linear assumption that consumption upgrading inevitably drives green innovation (Nordhaus, 2021). The negative moderation by labor force level revises the direct application of human capital theory in the green innovation domain (Costantini et al., 2017), offering new insights for regional innovation policy in populous countries like China. Third, methodologically, this study constructs a multi-level moderating effect analysis framework for Chinese economic environment, overcoming the limitation of existing research that focuses on single moderating factors (Hering and Poncet, 2014), achieving a more systematic and realistic depiction of complexity.

Literature Review

Theoretical Review

The concept of environmental taxation was first proposed by the welfare economist Pigou in 1932 (Marshall, 1920). The essence of green taxation is to reduce negative environmental externalities, such as pollution and excessive resource depletion, by levying taxes on activities

that perpetuate environmental degradation (Uddin et al., 2023). Norouzi et al. (2022) reconciled the definitions and nuances of green taxation, which has evolved from a single, specific green tax to encompass diverse tax instruments and strategies related to resource use and environmental protection (Shi et al., 2023; Saad and Ariffin, 2019). Deng and Huang (2020) refined the distinction of green taxation, categorizing it into narrow and broad scopes. The narrow perspective focuses primarily on pollutant emissions, while the broad perspective incorporates the synergistic development of the economy, ecology, and society. Mohammed (2020) adopted this classification, viewing the Environmental Protection Tax as representative of narrow green taxation and other environment-related taxes as constituting broad green taxation.

Joseph Schumpeter is widely regarded as the foundational figure in innovation research (Martin, 2012). In his seminal 1911 work, *The Theory of Economic Development*, based on a profound analysis of economic conditions, Schumpeter first introduced the concept of “innovation,” epochally asserting that “innovation is the most critical driver of economic development.” Green technology innovation serves as a core means to address global environmental pollution (Su et al., 2022). Green innovation can be characterized as the modification of processes, technologies, systems, and products aimed at mitigating or circumventing environmental problems (Franceschini et al., 2016; Kemp and Oltra, 2011; Rennings, 2000). Compared to traditional economic development models, green technological innovation plays a fundamental role in achieving sustainable development goals while minimizing adverse impacts on the natural environment (Lin et al., 2018; Luo et al., 2019).

Empirical Review

The Porter Hypothesis, proposed by the American economist Michael Porter, posits that environmental regulations, including environmental protection taxes, can incentivize firms to undertake greater technological innovation activities under appropriate design. This innovation can enhance productivity, reduce pollution emissions, and simultaneously achieve environmental protection and economic growth (Porter and van der Linde, 1995). Jaffe et al. (2005) and Pezzey et al. (2013) argued that tax-based instruments can exert a stronger promotional effect on green innovation in production technologies than other means. Empirically, Frondel (2007), utilizing OECD survey data and discrete choice models, found that environmental protection tax policies positively impact firms’ technological innovation inputs and outputs and promote cleaner production. Similarly, Franco and Marin (2015), employing manufacturing sector data from European countries, demonstrated that manufacturing firms’ innovation activities are closely linked to environmental regulatory activities, and well-designed regulatory policies can stimulate green technological innovation within the sector. Conversely, Filbeck (2004), focusing on electric utility companies, found that the costs imposed by environmental protection taxes reduced corporate economic efficiency, as the internalization of pollution’s negative externalities lowered operational efficiency.

Therefore, based on the research objectives, this study proposes the following hypothesis:

H1: Green Taxation Promotes Green Technology Innovation

Raza et al. (2023) found that economies with higher social consumption levels are better positioned to implement green taxation policies effectively. Similarly, Ahmad and Satrovic

(2024) indicated that monetary policy in developed economies can optimize the role of green innovation in environmental sustainability. Although social consumption levels generally enhance the effectiveness of green taxation, some studies caution against over-reliance on taxation without complementary policies. Khan et al. (2025) noted that in developing economies, green taxation alone may be insufficient due to weaker innovation infrastructure. If consumer sentiment towards technology is predominantly negative rather than positive, it inhibits the tendency to express environmental values through purchasing behavior (Parasuraman and Colby, 2015). Research found that while shocks reduced non-user consumption by 7%, household consumption among consumers remained unaffected (Jack and Suri, 2014).

Therefore, based on the research objectives, this study proposes the following hypothesis specific to the Chinese context:

H2: Social consumption level enhances the impact of green taxation on green technological innovation.

Human capital accumulation exerts a significantly positive influence on environmental technologies and green innovation (Costantini et al., 2017). Empirical evidence indicates complexity regarding labor force level: while it generally shows a significant positive impact on green technology innovation, critical thresholds exist. For instance, when employment density exceeds 6.7, the elasticity of green patent output turns negative. Empirical analysis of the US Silicon Valley cleantech cluster revealed that beyond this density threshold, a 1% increase in employment led to a 0.9 percentage point decline in green patent growth rates, attributed to efficiency losses in innovation resource allocation due to crowding effects (Bloom et al., 2020). However, institutional barriers weaken spatial synergies. For example, Chinese household registration restrictions resulted in the contribution of employment expansion in the western region to technology spillovers in the eastern region lower than within the EU (OECD, 2023). International talent mobility intensity, when increased by one standard deviation, augmented the elasticity coefficient of employment scale on green technology innovation by 0.21 (Keller, 2020). Thus, while the labor force level exhibits a significant positive association with green technology innovation, its role within the “green taxation to green technological innovation” mechanism involves complex moderating effects requiring deeper analysis.

Therefore, based on the research objectives, this study proposes the following hypothesis:

H3: Labor force level inhibits the impact of green taxation on green technological innovation.

Methodology

Variable Description

Following Yang (2024), this study categorizes green taxes into narrow and broad definitions. The narrow green tax (NGT) specifically targets pollutant emissions to promote environmental protection and sustainable development. This study uses the Environmental Protection Tax to represent narrow green taxation. Prior to environmental protection tax implementation, pollution discharge fees are used as its proxy, reflecting the transition from a fee-based system to a formal tax framework. Broad green taxation comprises eight taxes: environmental protection tax, resource tax, urban maintenance and construction tax, urban

land use tax, vehicle and vessel tax, farmland occupation tax, consumption tax, and vehicle purchase tax.

Green technology innovation (GTI), conceptualized by Braun and Wield (1994) as technologies reducing environmental impact and material consumption, is measured using patent counts following Su and Moaniba (2017) and Hu (2023). Provincial green patent applications are aggregated from prefecture-level data in the CNRDS Green Patent Database, summing green invention patents and green utility model patents. The logarithmic transformation of green patent applications represents green technology innovation.

Social consumption level and labor force level reflect Chinese economic system. Control variables include urbanization rate, human capital, fiscal support, technology market development, informatization level, and transportation infrastructure. Table 3.1 summarizes all variables.

Research Sample

This study analysis employs panel data from 30 Chinese provinces from 2007 to 2022). Due to data limitations, Tibet, Hong Kong, Macau, and Taiwan are excluded. Missing values are imputed using linear interpolation. Green patent data derive from the CNRDS Green Patent Database. Green tax data and other socioeconomic variables are sourced from the National Bureau of Statistics (NBS).

The sample underwent the following processing:(1) To mitigate the influence of outliers on the estimates, observations where variables fell below the 1st percentile or above the 99th percentile were deleted. (2) As Chinese Environmental Protection Tax was not implemented until 2018, pollution discharge fees were used to represent narrow green taxation prior to 2018. For missing green taxation data between 2016 and 2018, linear interpolation was employed to estimate the missing values. (3) Tibet, Hong Kong, Macau, and Taiwan are excluded from this study.

Empirical Model

We posit that green taxation influences green technology innovation, with covariates including urbanization, human capital, fiscal support, technology market development, informatization, and transportation infrastructure. Drawing on Jiajia and Runke's (2025) baseline specification, we establish a two-way fixed effects model:

Baseline Model

$$GTI_{it} = \beta_0 + \beta_1 GT_{it} + \sum_j \beta_j X_{it} + \mu_i + \omega_t + \varepsilon_{it}$$

To test moderating effect, this study incorporates Chinese economic environment as a moderating variable within a two-way fixed effects model, analyzing its moderating effect on the relationship between green taxes and green technology innovation. The following econometric specification is constructed:

Moderation Model

$$GTI_{it} = \beta_0 + \beta_1 GT_{it} + \beta_2 MO_{it} + \beta_3 (GT_{it} \times MO_{it}) + \sum_j \beta_j X_{it} + \mu_i + \omega_t + \varepsilon_{it}$$

In the above model: i and t denote province and year, respectively; GTI_{it} denotes green technology innovation; GT_{it} denotes narrow or broad green tax; $\sum_j \beta_j X_{it}$ is the set of control variables; MOV_{it} is the set of moderating variables; β_0 is the intercept; μ_i and ω_t are province and year fixed effects, ε_{it} is the stochastic disturbance term. The significance of β_3 indicates the moderating effect: If $\beta_3 > 0$ and statistically significant at the 5% level, it suggests that the moderating variable enhances the impact of green tax on green technology innovation. Conversely, a negative and significant β_3 implies an inhibiting effect (Wang, 2024; Wang et al., 2023).

Empirical Results and Discussion

Descriptive Statistics

Descriptive statistics for the study variables are presented in Table 4.1. The number of observations for all variables is 480. The mean, standard deviation, minimum and maximum values exhibit considerable variation across the variables. The mean value of green technology innovation is 7.592, while that of human capital level is only 0.02. Regarding standard deviation, green technology innovation has a standard deviation of 1.575, compared to 0.007 for human capital level, indicating that green technology innovation data are more dispersed while human capital level data are more concentrated. The range (difference between max and min) is larger for green technology innovation than for human capital level.

Table 4.1

Descriptive Statistics

variable	N	mean	sd	min	max
GTI	480	7.592	1.575	3.434	10.761
NGT	480	1.718	0.679	0.28	3.356
BGT	480	6.172	0.886	3.334	7.666
URB	480	0.576	0.133	0.323	0.893
HUM	480	0.02	0.007	0.007	0.044
FSI	480	0.246	0.108	0.097	0.758
TMDL	480	0.015	0.026	0	0.15
INFORM	480	0.064	0.048	0.015	0.29
TRSPORT	480	11.509	0.848	9.311	12.903

The results of Moderating Effect Analysis

Multicollinearity tests were conducted separately for the two independent variables, narrow green taxation and broad green taxation. The results indicate no severe multicollinearity issues among the variables in either dataset, confirming that all independent variables are uncorrelated. Subsequently, F-tests, Breusch-Pagan (BP) tests, and Hausman tests were performed for both narrow green taxation and broad green taxation. For both narrow green taxation and broad green taxation, the F-tests lead to the conclusion that the Fixed Effects Model is more consistent and efficient for this study.

Columns (1) and (2) in Table 4.2 present the baseline fixed-effects regression results examining the impact of green taxes on green technology innovation. Column (1) shows that the coefficient for the narrow green tax is 0.154, which is positive and statistically significant at the 1% level. This indicates that a one-unit increase in narrow green taxation is associated

with an average increase of 0.154 units in green technology innovation. Column (2) shows that the coefficient for the Broad Green Tax is 0.384, also positive and significant at the 1% level. This implies that a one-unit increase in broad green taxation leads to an average increase of 0.384 units in green technology innovation. Compared to narrow green taxation, the coefficient for broad green taxation is more than double and exhibits a higher level of significance. This suggests that broad green taxation has a significantly stronger driving effect on green technology innovation.

These regression results confirm that both the narrow green taxation and the Broad Green Tax exert a positive and significant promoting effect on Green Technology Innovation. Crucially, the promoting effect of broad green taxation is demonstrably stronger and more significant than that of narrow green taxation. Therefore, Hypothesis 1 is supported. This finding underscores that constructing a broad-coverage, highly integrated green tax system with strong policy signals is essential for effectively incentivizing green technology innovation. The two-way fixed effects model controls for time-invariant individual effects and individual-invariant time effects, enhancing the causal interpretability of the estimated coefficients for the core explanatory and control variables.

Table 1.2

Regression Analysis Results of Panel Data.

	(1) GTI	(2) GTI
NGT	0.154*** (4.34)	
BGT		0.384*** (4.31)
N	480	480
r ²	0.2684	0.2823

Note: The standard errors are reported in parentheses. Sample period: 2007–2022. Significance: *p < 0.1, **p < 0.05, ***p < 0.01.

Further analysis of the moderating effect of Chinese economic environment on the relationship between green taxation and green technology innovation is presented in Table 4.3. In Model (1), the independent variable narrow green taxation has a significant positive impact on Green Technology Innovation: a 1-unit increase in narrow green taxation corresponds to an average increase of 0.172 units in green technology innovation. This strongly supports the core argument of the Porter Hypothesis that “appropriate environmental regulation can stimulate innovation compensation,” echoing findings from Rubashkina et al. (2015) based on European firm-level data and confirming the fundamental role of environmental policy in incentivizing green technology development. However, the coefficient of the interaction term narrow green taxation and social consumption Level (NGT_CSUM) is significantly negative, indicating a moderating effect that is inhibitory: a 1-unit increase in social consumption level weakens the positive impact of narrow green taxation on green technology innovation by 0.710 units. For example, when social consumption level is high, the promotive effect of narrow green taxation on green technology innovation is substantially reduced. The main effect of social consumption level itself is not

significant, indicating that consumption level alone does not affect green technology innovation.

In Model (2), narrow green taxation has a significant positive impact on green technology innovation: a 1-unit increase corresponds to an average increase of 0.115 units. The interaction term between the moderator labor level and narrow green taxation (NGT_L) is significantly positive at the 1% level, with a coefficient of -0.402, indicating an inhibitory moderating effect. The main effect of labor level itself is not significant, indicating that labor level alone does not affect green technology innovation.

Table 4.3

Regression Analysis of Moderating Effects for Narrow Green Taxation

	(1) GTI	(2) GTI
NGT	0.172*** (5.30)	0.115*** (3.35)
CSUM	0.002 (0.01)	
NGT_CSUM	-0.710** (-2.11)	
L		-0.061 (-0.42)
NGT_L		-0.402*** (-6.17)
N	480	480
r ²	0.2983	0.3489

Note: The standard errors are reported in parentheses. Sample period: 2007–2022. Significance: *p < 0.1, **p < 0.05, ***p < 0.01.

In Table 4.4 Model (1), the independent variable broad green taxation has a significant positive impact on the dependent variable green technology innovation. Specifically, a 1-unit increase in broad green taxation corresponds to an average increase of 0.306 units in green technology innovation, indicating that green taxation promotes green technology innovation. The coefficient of the interaction term broad green taxation and social consumption level (BGT_CSUM) is -1.142, significantly negative, indicating an inhibitory moderating effect, consistent with the results for Narrow Green Taxation, and its inhibitory effect is stronger than that for narrow green taxation. Empirical results show that Social Consumption Level inhibits the impact of both narrow green taxation and broad green taxation on green technology innovation, hypothesis H2 is rejected. This aligns with existing empirical research suggesting that excessively high consumption levels may weaken the innovation investment incentives induced by green taxes (Acemoglu et al., 2012), but contradicts studies indicating that consumers' increasing environmental awareness and willingness to pay significantly reduce market risks and uncertainties for firms adopting green technologies and developing eco-friendly products (Zhu et al., 2014), thereby promoting the effect of green taxation on green technology innovation. This suggests that current acceptance of green products by Chinese consumers needs improvement.

In Model (2), broad green taxation has a significant positive impact on green technology innovation: a 1-unit increase corresponds to an average increase of 0.315 units. The coefficient of the interaction term broad green taxation and labor level (BGT_L) is significantly negative, indicating an inhibitory moderating effect, consistent with the results for narrow green taxation. Empirical results indicate that Labor Level inhibits the impact of green taxation on green technology innovation, Hypothesis H3 is supported. This result differs from Dechezleprêtre et al. (2023), who found that firms with highly skilled workforces are more capable of investing in green technology R&D and more effectively translating R&D outcomes into market competitiveness. This suggests that China should currently focus on cultivating high-quality talent and providing green technology training for the existing workforce to adapt to new technologies.

Table 4.4

Regression Analysis of Moderating Effects for Broad Green Taxation

	(1) GTI	(2) GTI
BGT	0.306*** (3.45)	0.315*** (3.56)
CSUM	-0.004 (-0.02)	
BGT_CSUM	-1.142*** (-4.57)	
L		-0.046 (-0.28)
BGT_L		-0.086*** (-3.72)
N	480	480
r ²	0.3289	0.3162

Note: The standard errors are reported in parentheses. Sample period: 2007–2022. Significance: *p < 0.1, **p < 0.05, ***p < 0.01.

Robustness Tests*Lagged Independent Variables*

To mitigate potential reverse causality and other endogeneity concerns, this study re-examined the hypotheses using independent variables lagged by one period. The results, presented in Table 4.5, confirm that the moderating effects remain robust after this adjustment. This strongly indicates that our core findings are empirically reliable and stable.

Table 4.5

Robustness Test Results: Lagged Independent Variables

	(1) GTI	(2) GTI	(3) GTI	(4) GTI
L.NGT	0.167*** (4.33)	0.157*** (4.32)		
CSUM		0.012 (0.05)		
L.NGT_CSUM		-1.532*** (-4.33)		
L.BGT			0.441*** (5.05)	0.360*** (4.11)
L				-0.114 (-0.60)
L.BGT_L				-0.117*** (-4.94)
_cons	2.128*** (2.77)	2.383*** (2.91)	1.254 (1.53)	1.778** (2.02)
N	450	450	450	450
r2	0.2214	0.2586	0.2433	0.2947

Note: The standard errors are reported in parentheses. Sample period: 2007–2022. Significance: *p < 0.1, **p < 0.05, ***p < 0.01.

Control Variable Adjustment

Further tested robustness by excluding the control variable TRSPORT. Results in Table 4.7 confirm that the core conclusions remain unchanged, underscoring the reliability and stability of our findings.

Table 4.6

Robustness Test Results: Control Variable Adjustment

	(1) GTI	(2) GTI	(3) GTI	(4) GTI
NGT	0.146*** (4.11)	0.100*** (2.69)		
BGT			0.350*** (3.98)	0.372*** (4.24)
CSUM	0.230 (0.98)		0.188 (0.80)	
NGT_CSUM	-1.070*** (-3.10)			
L		0.196 (1.29)		0.131 (0.76)
NGT_L		-0.343*** (-5.11)		
BGT_CSUM			-1.186*** (-4.74)	
BGT_L				-0.067***

				(-2.70)
_cons	5.025*** (16.80)	3.138** (2.44)	4.402*** (9.11)	2.860** (2.01)
N	480	480	480	480
r2	0.2447	0.2761	0.2885	0.2681

Note: The standard errors are reported in parentheses. Sample period: 2007–2022. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Conclusions and Policy Recommendations

This study systematically examines the impact mechanism of green taxes on green technology innovation using provincial panel data from China (2007–2022) and a rigorously constructed moderating effects model. It specifically highlights the critical moderating role of Chinese multidimensional economic environment. Core empirical findings reveal that the driving effect of Broad Green Taxes on green technology innovation is significantly stronger than that of narrow green taxation. This underscores the paramount importance of establishing a comprehensive green tax system characterized by broad coverage, high integration, and clear policy signals. An extensive tax base design more effectively internalizes diverse environmental externalities, providing stronger and more stable innovation incentives to microeconomic agents (Popp, 2019; Metcalf, 2019). Compared to narrow green taxation focusing solely on end-of-pipe pollutants, the broad green taxation framework achieves more comprehensive market failure correction and systematically channels production factors toward green innovation (Acemoglu and Restrepo, 2022). These results strongly support the applicability of the Porter Hypothesis in complex economies, affirming that well-designed environmental regulation can stimulate innovation and enhance competitiveness (Porter and van der Linde, 1995), while further emphasizing tax system *breadth* as the core policy lever for achieving this outcome.

Regarding moderating effects, this research uncovers complex and pivotal mechanisms of Chinese economic environment, with some findings challenging conventional wisdom. Social consumption level exerts a significant *negative* moderate effect on the green tax- green technology innovation relationship. This implies that in high-consumption regions, the innovation-inducing effect of green taxes is weakened. The theoretical explanation traces back to the manifestation of *Baumol's cost disease* in the green innovation context (Nordhaus, 2021). High consumption often coincides with service-sector dominance and entrenched resource-intensive consumption patterns, elevating the cost structure of economic activities. Firms prioritize allocating resources to meet existing high-demand production/services over long-cycle, high-risk green R&D (Aghion et al., 2016). Even under green tax pressure, firms may opt for tax absorption or end-of-pipe mitigation rather than fundamental green innovation (Lanoie et al., 2011), revealing structural barriers to green transition in consumer-driven economies. Labor force level similarly exhibits a significant negative moderating effect. In regions with large labor pools (e.g., manufacturing or populous provinces), firms' reliance on low-cost labor means increased green taxes raise operational costs, crowding out innovation investment. Surplus labor further diminishes innovation incentives, contrasting with literature suggesting human capital accumulation invariably promotes green innovation (Costantini et al., 2017).

This study significantly deepens the integration of environmental economics and innovation research at the theoretical level. The results provide strong support for the central role of environmental policy in stimulating Green Technology Innovation (Popp, 2019). More crucially, they reveal the high sensitivity of policy effectiveness to the breadth of the tax system and the regional economic context.

At the policy level, this study offers precise navigation for China and similar economies to optimize green taxation policies and synergistically advance pollution and carbon reduction alongside innovation-driven development. The primary recommendation is to accelerate the construction and optimization of a Broad Green Taxation system. This requires not only consolidating and strengthening the existing environmental protection tax but also systematically integrating related taxes such as resource tax, consumption tax, vehicle purchase tax, and urban land use tax to enhance policy synergy and signal clarity (Metcalf, 2019; Klenert et al., 2018). Secondly, policy design must meticulously account for regional economic heterogeneity. In regions with high social consumption levels, strong green consumption guidance policies and supply-side structural reforms are needed. In labor-intensive regions, efforts should focus on enhancing the alignment between the labor skill structure and green industry demands, optimizing regional industrial layouts to alleviate congestion effects from excessive agglomeration, while simultaneously removing institutional barriers to labor mobility to promote effective knowledge spillovers across regions (Bloom et al., 2019).

This study examines the effect of green taxation on green technological innovation based on the Porter hypothesis. These empirical results indicate that when formulating and implementing green tax policies to promote green technological innovation, it is necessary to fully consider the differences in key economic factors such as regional consumption structure and labor conditions, as well as their complex interaction mechanisms. Differentiated green taxes can promote green technological innovation and achieve sustainable development goals. This study provides policy insights for optimizing green fiscal tools to promote innovation-driven sustainable development.

Despite the advances achieved in this study, several promising directions remain for future research. The primary direction is to expand cross-national comparative studies. Future research could select countries at different development stages and with distinct institutional backgrounds, such as the European Union, the United States, India, and Brazil, applying a similar framework for comparative analysis.

Declaration of Conflicting Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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