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Green Taxes and Fees Competition and Productivity Growth: Evidence from China

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Green Taxes and Fees Competition and Productivity Growth: Evidence from China

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Abstract

A central tenet in the fiscal federalism literature posits that inter-jurisdictional tax competition can engender economic efficiency losses. However, diverse firms exhibit heterogeneous sensitivities to varying tax burdens. When firms strategically evaluate differential tax pressures across tax categories, tax competition evolves into competition over tax structure. This dynamic is particularly pronounced in the case of green taxes and fees, which aim to internalize negative externalities compared to conventional tax instruments. We identify a “race to the bottom” phenomenon in corporate green taxes and fees driven by structural distortions within the tax system in China. Based on the constructed theoretical model of energy factor allocation that includes a distortionary coefficient of green taxes and fees, we predict that the efficiency growth of firms will decrease as the intensity of their “race to the bottom” competition increases in response to the relative pressure of green taxes and fees. Using data from listed companies in China, we find a robust negative relation between the “race to the bottom” competitive intensity of green taxes and fees pressure and total factor productivity growth. Our findings indicate that increasing the intensity of fiscal and environmental decentralization exacerbates the problem of the intensity of competition in the corporate tax structure, generating significant efficiency losses. These findings provide new evidence on the economic disadvantages of unchecked tax competition in decentralized systems.

Keywords: green taxes and fees, competition, energy misallocation, total factor productivity growth

JEL Codes: H23, P28, Q56

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1. Introduction

The trade-offs between centralization and decentralization in federal states have been extensively documented in the literature (Oates, 1999). Second-generation fiscal federalism theory (Oates, 2008; Weingast, 2009) emphasizes that an optimal allocation of taxing authority and expenditure responsibilities across government levels—guided by informational advantages and incentive structures—is crucial for maximizing the social benefits of public goods. However, the debate on the relative merits of centralization versus decentralization remains unresolved. As highlighted by Besley and Coate (2003), the comparative advantages of these systems largely depend on the extent of public good spillovers and regional preference heterogeneity. While centralization can effectively internalize cross-jurisdictional externalities, it often overlooks local-specific conditions and endowments (Goulder and Stavins, 2011). Conversely, decentralization enhances local information utilization and strengthens fiscal incentives (Shah, 2006; Gadenne and Singhal, 2014), but may exacerbate inter-jurisdictional externalities.¹

Environmental federalism, an extension of fiscal federalism, applies a similar framework to the centralization-decentralization debate but shifts the focus from fiscal instruments to environmental regulation. A key contention in this domain is whether decentralization incentivizes local governments to engage in regulatory competition, potentially leading to a “race to the bottom” in environmental standards and consequent efficiency losses or environmental degradation. The theoretical foundation posits that decentralization widens the informational asymmetry between central and local governments, potentially compromising the central government’s capacity to effectively monitor local fiscal operations, including revenue utilization, expenditure allocation, and public service delivery (Martinez-Vazquez, 2021). In practice, the degree of fiscal decentralization and the stringency of environmental regulations must be carefully calibrated. This is because variations in regulatory intensity across jurisdictions influence firms’ strategic responses as they seek to maximize benefits or minimize costs under differing incentive structures.

A classic issue concerning the disadvantages of decentralization under federalism is tax competition (Oates, 1972). A key question is whether local governments, following tax system decentralization, strategically reduce effective tax rates to attract mobile resources. If so, local government officials may increase their willingness to compete for tax revenues (Oates and Schwab, 1988), such as be amplified by the career incentives embedded in the promotion tournament system (Li and Zhou, 2005), which triggers firms to “vote with their feet” (Tiebout, 1956) to create the phenomenon of “race to the bottom” (Wilson, 1999; Dijkstra and Fredriksson, 2010). This inter-jurisdictional tax competition phenomenon is observed across developed and developing federal systems (Janeba and Wilson, 2011). Therefore, this issue has been well documented in the previous literature, with relevant studies focusing on capital taxation (Bucovetsky, 1991; Wilson and Wildasin, 2004; Mongrain and Wilson, 2018) or economic efficiency (Zodrow and Mieszkowski, 1986; Keen and Marchand, 1997; Zissimos and Wooders, 2008), and in terms of international tax competition (Janeba, 2000; Slemrod and Wilson, 2009; Buettner and Poehnlein, 2024).

However, the fiscal and environmental federalism literature has limitedly addressed the inter-jurisdictional competition surrounding green taxes and fees, such as sewage charges and environmental protection taxes. This gap persists despite its relevance to developed and developing countries, and the urgency of adapting public policies, including decentralization reforms, to fight climate change, thus leaving the existence, mechanisms, and economic consequences of such

¹ Local elections and certain forms of party institutions must be in place before we can expect decentralization to deliver on its promises (Ponce-Rodríguez et al., 2018).

competition as an open empirical question. Addressing this gap is crucial for refining decentralized systems of green taxation and informing the design of environmental policy enforcement. While the original policy intent behind green taxes and fees was to empower local governments to leverage local information for pollution reduction and green economic development, the profit-maximizing behavior of firms introduces complexities. As rational economic agents, enterprises seek to mitigate the cost impact of green taxes and fees, potentially undermining policy objectives. We identify a novel phenomenon of “race to the bottom” competition on the relative pressure of corporate green taxes from the perspective of distortions in the tax structure, providing new evidence on the drawbacks of unchecked tax competition in decentralized regimes. In this regard, we first try to characterize enterprises’ “race to the bottom” competitive behavior in response to the pressure of sewage charges and environmental protection tax. Then, based on the constructed theoretical model of energy factor allocation that includes the distortionary coefficients of green taxes and fees, we predict that the total factor productivity growth of firms will decrease as the intensity of their competition against the relative pressures of green taxes and fees increases in a “race to the bottom” manner, and that energy misallocation is the primary mechanism of influence.

We empirically test our hypotheses using data from China, which provides an ideal institutional setting for examining our core propositions. First, China’s fiscal federalism system exhibits significant decentralization (Jin et al., 2005; Liu et al., 2017; Lyu et al., 2022). The central government has decentralized the collection and management of sewage charges and environmental protection tax to local governments, fostering conditions for inter-regional competition. On the other hand, local governments have the authority to implement tax incentives within their prescribed fiscal powers while competing to attract financial resources from other regions.

Second, China’s environmental federalism framework (Zhang et al., 2018; Wu et al., 2025) grants local governments discretion in implementing green taxes and fees. While the central government establishes baseline standards for sewage charges and environmental protection tax, local governments can adjust these standards according to regional conditions. This has resulted in substantial variation in environmental tax burdens across regions. For instance, the applicable tax amounts for taxable air pollutants in Beijing, Tianjin, Jiangsu, and Chongqing are 12 yuan, 10 yuan, 4.8 yuan, and 3.5 yuan per pollution equivalent. Moreover, the collection standards of sewage charges and environmental protection tax vary among different provinces and at various times. For example, Shanghai’s tax standards for sulfur dioxide and nitrogen oxides were 6.65 yuan and 7.6 yuan per pollution equivalent in 2018, while they were raised to 7.6 yuan and 8.55 yuan per pollution equivalent in 2019, respectively. This cross-regional and temporal variation provides an empirical basis for studying firm responses to green taxes and fees pressures.

Third, China’s regulatory framework for environmental taxation, as stipulated in the Regulation on the Administration of Collection and Use of Pollutant Discharge Fees and the Environmental Protection Tax Law, establishes that the primary tax burden for green taxes and fees falls exclusively on enterprises, with explicit provisions prohibiting the shifting of these fiscal obligations to individual consumers. Firms face a strategic trade-off between environmental compliance and economic growth, creating incentives to minimize their environmental tax burden through various means, such as pollution shifting (Bartram et al., 2022) and energy input adjustments. Fourth, China’s promotion tournament system incentivizes local officials to prioritize economic growth metrics for career advancement (Li and Zhou, 2005). This political economy context may lead some officials to tolerate environmental degradation in exchange for short-term economic gains, creating opportunities for firms to engage in rent-seeking behavior and compete to reduce their green tax obligations.

Our empirical analysis employs data from Chinese listed companies spanning 2007–21 to examine whether firms’ “race to the bottom” competitive intensity in response to the relative pressure of green taxes and fees leads to a decline in total factor productivity growth. This period encompasses the 2018 policy transition from sewage charges to environmental protection tax, which provides a unique opportunity to study the dual features of fiscal and environmental federalism. The policy shift exhibits two key characteristics that enhance our analysis. First, while sewage charge revenues were previously shared between central and local governments (10 percent and 90 percent, respectively), environmental protection tax revenues are entirely allocated to local governments, strengthening fiscal decentralization incentives. Secondly, despite maintaining the same tax base, the policy changes increased collection standards and enforcement intensity, effectively enhancing environmental regulation. This institutional setting creates a strategic trade-off for firms between environmental compliance costs and potential economic benefits. Furthermore, the interplay of fiscal and environmental federalism has resulted in significant spatial and temporal variation in sewage charges and environmental protection tax standards across provinces, providing valuable empirical variation for our study.

Leveraging this variation, we empirically find a negative relation between the “race to the bottom” competitive intensity of the relative pressure of green taxes and fees on firms and the magnitude of total factor productivity growth. However, the “race to the bottom” competitive behavior of firms with relative pressure to green taxes and fees is endogenous. The smaller the increase in firms’ total factor productivity, the more likely firms will intensify the intensity of their competition for green taxes and fees pressures. To address this endogeneity problem, we draw on the constructive ideas of the Bartik shift-share instrumental variable method (Bartik, 1991). First, we take the ratio of green taxes and fees of each industry in each province to the total taxes and fees in each province with a two-period lag as the initial taxes and fees structure. Second, we calculate the growth rate of each firm’s competitive intensity of green taxes and fees from 2008 to 2021. Finally, we interact each province’s initial taxes and fees structure with the growth rate of firms’ green taxes and fees competitive intensity to obtain the Bartik instrumental variable. Instrumental regression results show a robust negative correlation between the intensity of firms’ “race to the bottom” competition over the relative pressure of green taxes and fees and total factor productivity growth. In addition, the benchmark regression results survive a series of robustness checks. We remeasured and replaced the independent and dependent variables, continued to add firm-level and county-level control variables, changed the empirical data sample, and excluded changes in total taxes and fees. These tests yielded similar results, demonstrating the robustness of the benchmark findings.

We further investigate the mechanisms through which corporate competition in green taxes and fees affects total factor productivity growth. Our analysis reveals that corporate green taxes and fees pressure “race to the bottom” competition indirectly inhibits total factor productivity growth, mainly by increasing the degree of energy factor misallocation. The moderating mechanism suggests that the dampening effect of the intensity of green taxes and fees competition on efficiency growth changes with the firm’s energy factor output elasticity, technological innovation, and output share. Firms exhibiting higher energy output elasticity, more technological innovation, and larger output shares tend to engage more aggressively in green tax competition, thereby experiencing more pronounced efficiency losses.

Our heterogeneity analysis yields additional insights. Following the policy transition from sewage charges to environmental protection tax, stricter environmental regulations paradoxically intensify competitive incentives among high-polluting firms. This heightened competition in response to green taxes and fees pressures leads to more pronounced declines in total factor productivity growth. The “race to the bottom” effect significantly varies across firm types. The policy shock is particularly acute

for state-owned enterprises (SOEs) and greenwashing firms while being somewhat mitigated in high-technology firms. This pattern suggests that while stronger environmental regulations address enforcement deficiencies in the sewage charge system, they may inadvertently reinforce rent-seeking behaviors. Specifically, SOEs facing budgetary constraints and greenwashing firms engaged in environmental propaganda are particularly motivated to intensify their tax competition. Furthermore, these regulatory measures may distort technological greening transformation efforts, even among high-tech polluting firms.

This paper contributes to three strands of literature. First, since the 1980s, the fiscal federalism literature has focused on local governments' tax competition. The competitive behavior of local governments in decentralized systems for different taxes "race to the bottom," such as property taxes (Lyytikäinen, 2012), capital taxes (Janeba and Osterloh, 2013), and sales taxes (Buettner and Poehnlein, 2024), has been important causes of economic efficiency losses (Wilson, 1999). However, this literature has largely overlooked the distortionary effects of tax structure competition. Our research addresses this gap by demonstrating how firms' heterogeneous responses to varying tax burdens, particularly their "race to the bottom" behavior regarding the share of green taxes and fees in total taxes and fees burden, contribute to energy factor misallocation and productivity losses. Developed and developing countries have recently improved tax policies to provide more substantial incentives to promote economic development and protect the environment. However, the distorting effects of tax structures have been neglected, especially the structural effects between green taxes and fees, which are characterized by correcting negative externalities and other taxes and fees. By shifting the focus from tax competition to tax structure competition, our study enriches the theoretical framework of fiscal federalism and tax competition.

Second, our study contributes to the environmental federalism literature, which has primarily focused on whether decentralization leads to a "race to the bottom" in environmental standards. The prevailing view among scholars on the effects of environmental regulatory policies under decentralized regimes is that the impact of emission reductions is closely related to the intensity of environmental regulation (Fredriksson and Millimet, 2002; Millimet, 2003). However, environmental regulatory measures may sometimes induce local governments to generate strategic responses, leading to more severe pollution spillovers between jurisdictions (Xie and Yuan, 2023; Li, 2025). This paper reveals the drawbacks of decentralization in environmental federalism by presenting evidence of energy misallocation and efficiency losses resulting from firms' "race to the bottom" competitive behavior in response to the relative pressures of green taxes and fees. In particular, after the change from sewage charges to environmental protection tax, the intensity of environmental regulation has increased, leading to green taxes and fees "race to the bottom" competitive behavior, further aggravating enterprises' productivity loss. The finding of this poor result is similar in spirit to the aforementioned studies of strategic policy spillovers by Xie and Yuan (2023) and Li (2025). We demonstrate that stronger environmental regulations can paradoxically create more significant incentives for firms to compete in tax, ultimately undermining productive efficiency. As an institutional mechanism, this suggests that environmental decentralization carries inherent risks of strategic firm behavior and efficiency losses in the context of green taxes and fees.

Third, our research contributes to the extensive literature on resource misallocation and productivity losses. Previous studies have identified various factors contributing to inefficiencies, including tax competition in fiscal federalism (Zodrow and Mieszkowski, 1986; Keen and Marchand, 1997; Zissimos and Wooders, 2008) and strategic environmental regulation in environmental federalism (Grossman and Krueger, 1995; Lanoie, 2008; Axbard and Deng, 2024). Our study advances this literature in three significant ways. First, we bridge the gap between fiscal and environmental federalism by examining the efficiency impacts of green tax competition, providing a

theoretical framework that integrates fiscal federalism, environmental federalism, and economic growth theories to elucidate the economic drawbacks of decentralized systems. Second, we identify energy factor misallocation as the primary mechanism through which green tax competition inhibits efficiency growth, offering actionable insights for local governments to mitigate such competitive behaviors. Third, we uncover the regulatory mechanisms and heterogeneous firm responses to green tax pressures, providing empirical evidence that informs the design of decentralized systems in federal states to better regulate competitive behaviors.

The remainder of this paper is organized as follows. Section 2 provides the institutional background and characteristic facts. Section 3 constructs a simple theoretical model and presents theoretical predictions. Section 4 introduces our econometric strategy. Section 5 presents the main results, robustness check, and mechanism analysis. Section 6 concludes the paper.

2. Institutional background and characteristic facts

2.1 Green taxes and fees

Green taxes and fees represent a class of environmental policy instruments that impose charges or taxes on polluters based on the “polluter pays” principle. These measures target various pollutants, including sewage, exhaust emissions, solid and hazardous waste, and noise pollution. The primary components of green taxation encompass sewage disposal fees, exhaust emission charges, solid and hazardous waste disposal fees, noise pollution levies, environmental protection taxes, and natural resource taxes, all designed to promote environmental protection and conservation. Among these instruments, sewage charges and environmental protection taxes are particularly significant. Both are effective regulatory tools for internalizing environmental externalities associated with pollution (Smulders and Gradus, 1996). These mechanisms align economic incentives with environmental objectives by ensuring that polluters bear the costs of their environmental impacts.

2.1.1 Sewage charge

In 1976, the former Federal Republic of Germany pioneered the implementation of the Waste Water Charging Act, marking the world's first specialized legislation governing sewage charging systems. This policy innovation subsequently influenced other nations, including Japan and China, to adopt similar systems and expand their scope to encompass exhaust emissions, waste, and other environmental hazards. The sewage charging system operates on the principle that polluters must compensate the state based on the type, quantity, and concentration of pollutants emitted, thereby internalizing negative externalities and enforcing the “polluter pays” principle. This system effectively addresses the divergence between private and social marginal costs by altering resource price signals, incentivizing polluters to enhance operational management, controlling both existing and new pollution sources, and improving energy efficiency. While it continues to play a significant role in environmental management, particularly in developing countries, the sewage charging system faces several limitations. These include insufficient enforcement mechanisms, excessive government intervention, and challenges verifying enterprise-reported data (Chen et al., 2014; Maung et al., 2016). These shortcomings have led to evasion behaviors among some enterprises, particularly in developing countries, commonly resulting in local government revenues from sewage charges falling below the operational costs of pollution control and undermining the system's effectiveness in incentivizing pollution reduction.

In China, the administrative basis for sewage charges is mainly the Regulations on the Administration of the Collection and Use of Sewage Charges. It clarifies that sewage charges are levied on units and individual industrial and commercial households that discharge pollutants directly into the environment and that the revenue from the levy is shared between the central government and local governments in the ratio of 1:9. To ensure the efficiency of the environmental protection authorities in enforcing the collection of sewage charges, the Regulations stipulate the following basic principles: charging for sewage disposal, mandatory collection, payment by a specified date, informatization of management, openness of government affairs, and the possibility of applying for a deferral of payment of sewage charges by the regulations, and so on. From 2003 to 2015, the country collected 211.599 billion yuan in sewage charges; the number of enterprises, institutions, and individual business households that paid sewage charges was more than 5 million. Among them 2015, 17.3 billion yuan was collected in sewage charges, with 280,000 households paying the charges. However, while the sewage fee system has played a role in preventing and controlling environmental pollution, it has also created considerable negative constraints: First, the levy standard is lower than the cost of pollution treatment. In 2014, China raised the sewage fee levy standard for major pollutants in sewage and exhaust gas to 1.4 yuan and 1.2 yuan, respectively, and levied a separate standard for the five major heavy metal pollutants of 1.4 yuan per pollutant equivalent. Still, it is far below the treatment costs of 2.46 yuan and 2.1 yuan per pollution equivalent for sewage and exhaust gas. Secondly, administrative interference by local governments has always existed, and they have the power to adjust the standards for collecting sewage charges. Some regions emphasize economic development over environmental protection and even designate “no-waste zones” and “quiet days for enterprises” to exchange economic revenues for tacit approval of environmental pollution without collecting sewage charges. China stopped collecting sewage charges in 2018 and proposed a smooth transfer to an environmental protection tax system to address these issues.

2.1.2 Environmental protection tax

Environmental protection taxes are a standard environmental and economic policy in developed countries, including energy, waste disposal, transportation, and water pollution taxes. For example, the United States and Germany have introduced oil taxes, the United Kingdom has introduced an energy regulation tax, Finland has introduced a carbon dioxide tax, and the United States has introduced solid waste disposal taxes such as a beverage container and tire tax. Germany and the Netherlands have introduced a water pollution tax. These developed countries levy different environmental protection taxes according to their environmental conditions and levels of economic development, relying on tax leverage so that enterprises with low production efficiency and high pollutant emission intensity pay more taxes, and enterprises with high production efficiency and low pollution emission intensity pay less taxes, effectively promoting green economic development. The economic principles it follows can be traced back to Pigou: environmental protection is affected by externalities, there is a market failure, damaging the optimization of social welfare, and it is necessary to correct the market failure through tax policies. The introduction of an environmental protection tax regulates government intervention in the market behavior at the same time but also helps to force high-pollution, high-energy consumption enterprises to transform and upgrade.

After fully realizing the problems of insufficient enforcement and high administrative intervention in the sewage fee system, the Chinese government began implementing the Environmental Protection Tax Law in 2018, marking the establishment of China's first tax aimed at environmental protection. China's environmental protection tax was leveled from the sewage fee system. It sets tax items based on the original sewage fee program, treats sewage fee payers as taxpayers of the environmental

protection tax, treats the amount of taxable pollutants emitted as the basis for tax calculation, and treats the original sewage fee charge as the lower limit of the tax amount for the environmental protection tax. The differences between the environmental protection tax and sewage charges are firstly, the tax reduction bracket for enterprise emission reduction has been increased, and the environmental protection tax is reduced by 75 percent if the concentration value of taxable air pollutants or water pollutants discharged by taxpayers is less than 30 percent of the prescribed standard. Secondly, the collection work is handed over to the tax department for implementation, increasing the standardization and rigidity of law enforcement and improving the efficiency of environmental protection tax collection through information sharing and collaborative work between the tax department and the environmental protection department.

Third, recognizing substantial interprovincial variations in environmental pollution levels and economic fundamentals, China's legislative framework grants local authority discretionary power to adjust tax rates within prescribed limits. Specifically, the Environmental Protection Tax Items and Amounts Table establishes baseline ranges for pollutant taxation (e.g., 1.2-12 yuan per pollution equivalent for air pollutants; 1.4-14 yuan per pollution equivalent for water pollutants), while permitting provincial governments to calibrate specific rates according to regional circumstances. This flexible taxation mechanism enables localized policy responses that account for heterogeneous environmental and economic conditions across jurisdictions. Fourth, the environmental protection tax has been fully incorporated into local fiscal revenue systems. According to official statistics from China's Ministry of Finance, environmental protection tax revenues amounted to 21.1 billion yuan in 2022, marking a 3.9-percent increase from the previous year. More notably, the share of environmental protection tax in total local tax revenue has demonstrated consistent growth, climbing from 0.199 percent in 2018 to 0.275 percent in 2022, reflecting its increasing significance within China's fiscal framework. This policy innovation has successfully institutionalized the "polluter pays" principle, effectively addressing the longstanding environmental governance challenge where "enterprises generate pollution, the public bears the consequences, and the government assumes the costs."

Existing literature has predominantly examined the direct effects of environmental policies, including environmental investments, emission reductions, and firm performance (Chiroleu-Assouline and Fodha, 2014; Han and Li, 2020; Liu et al., 2022; Jin et al., 2024). However, less attention has been paid to potential policy shocks arising from firms' strategic responses and economic consequences. From a cost-benefit perspective, sewage charges and environmental protection tax increase production costs. Consequently, firms in profit-driven markets, particularly high-polluting industries across developed and developing countries, face strong incentives to engage in competitive behaviors to reduce their environmental tax burdens. China's experience with sewage charges and environmental protection tax, developed over an extended period to balance rapid economic growth with environmental protection (see Table 1), provides a valuable institutional context for research. This study leverages China's policy implementation to investigate productivity losses and underlying mechanisms resulting from firms' competitive responses to green taxes and fees pressures under decentralized systems. The findings offer empirical insights relevant to decentralized countries (federal and non-federal or unitary) implementing similar environmental taxation systems.

Table 1

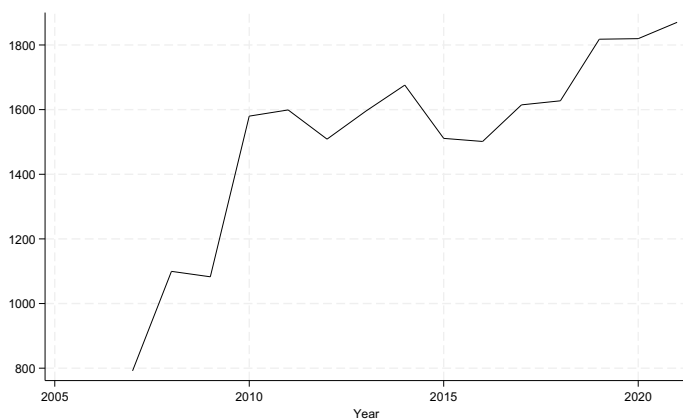
The China State Council decrees issued on the adjustment of green taxes and fees system.

File name	Date Issued	Effective Date	Source
Interim Measures for the Collection of Sewage Charges	02/05/1982	07/01/1982	pkulaw.cn, CLI.2.1191 (citing code)
Notification of Sewage Disposal Charges	07/10/1993	08/15/1993	pkulaw.cn, CLI.4.14063 (citing code)
Regulation on the Administration of Collection and Use of Pollutant Discharge Fees	01/02/2003	07/01/2003	pkulaw.cn, CLI.2.44492 (citing code)
Notice on Adjustment of Sewage Charge Collection Standards and Other Related Issues	09/01/2014	09/01/2014	pkulaw.cn, CLI.4.233357 (citing code)
Environmental Protection Tax Law of the People's Republic of China	12/25/2016	01/01/2018	pkulaw.cn, CLI.1.287291 (citing code)
Regulation on the Implementation of the Environmental Protection Tax Law of the People's Republic of China	12/25/2017	01/01/2018	pkulaw.cn, CLI.2.307655 (citing code)
Environmental Protection Tax Law of the People's Republic of China (2018 Revision)	10/26/2018	10/26/2018	pkulaw.cn, CLI.1.325024 (citing code)

2.2 Facts characterizing competition from green taxes and fees pressures

Based on the data samples of Chinese listed companies, we analyze the change characteristics of the competition phenomenon of the “race to the bottom” of green taxes and fees. This will provide basic facts and intuition for the theoretical analysis and empirical test in the following sections.

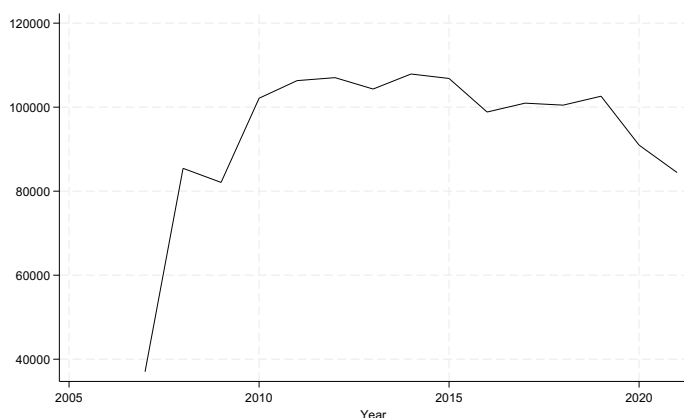
Fig. 1 Average value of actual sewage charge and environmental protection tax paid by listed companies from 2007 to 2021 (Unit: CNY 10,000).



Data source: *China Listed Companies Database*.

Figure 1 illustrates the changes in the average value of sewage charges and environmental protection tax paid by listed companies in China from 2007 to 2021. The evolution of environmental taxation among Chinese listed companies exhibits three distinct phases between 2007 and 2021. The initial phase (2007–10) witnessed rapid growth in average sewage charges, attributable to three key factors: (1) post-2008 economic recovery, (2) upward adjustments in provincial collection standards, and (3) enhanced regulatory enforcement of charge collection. During the intermediate phase (2011–17), sewage charges stabilized with minor fluctuations. The final phase (2018–21) saw sustained annual increases following the implementation of the Environmental Protection Tax Law, which replaced the sewage charge system. This institutional transition addressed critical limitations of the previous regime, particularly regarding enforcement rigidity and administrative interference, leading to consistent revenue growth in environmental taxation.

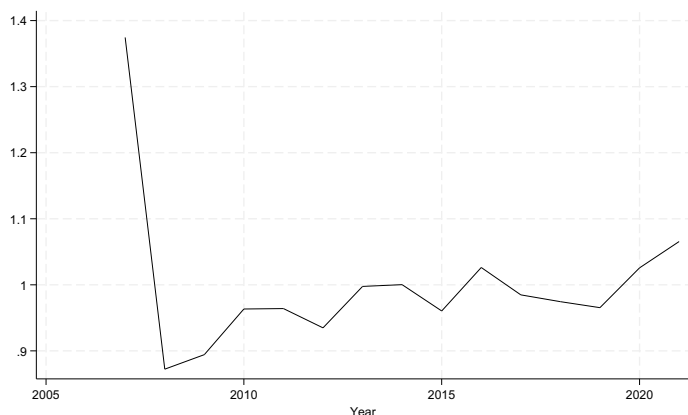
Fig. 2 Average value of actual payment of total taxes and fees by listed companies from 2007 to 2021 (Unit: CNY 10,000).



Data source: *China Listed Companies Database*.

Figure 2 presents the temporal evolution of average tax burdens for Chinese listed companies from 2007 to 2021, revealing four distinct phases. The initial recovery phase (2007–10) shows substantial growth in tax payments, corresponding with post-crisis economic expansion and broadening tax bases. This is followed by a stabilization phase (2011–15) with relatively constant tax burdens. The third phase (2016–19) exhibits a characteristic decline-then-stabilization pattern, likely reflecting the systemic impact of China's comprehensive Business-to-Value-Added Tax reform implemented in 2016. The final phase (2020–21) demonstrates pandemic-induced reductions across all tax categories. Comparative analysis with Figure 1 reveals generally parallel trends between sewage charges and total tax burdens during 2007–17. However, this correlation reverses sharply following the 2018 policy transition from sewage charges to environmental protection taxes, suggesting fundamentally different response mechanisms to these two fiscal instruments.

Fig. 3 Average value of green taxes and fees competition (GTFC) of listed companies from 2007 to 2021.



Data source: *China Listed Companies Database*.

Building upon Haggett's (1965) location quotient theory, we conceptualize our core explanatory variable, green taxes and fees competition intensity (GTFC), as a measure of comparative competitive advantage in environmental taxation. Formally, GTFC is defined as:

$$GTFC_{it} = \frac{\frac{Total\ Taxes\ and\ Fees_{it}}{Green\ Taxes\ and\ Fees_{it}}}{\frac{Total\ Taxes\ and\ Fees_{it}}{Green\ Taxes\ and\ Fees_{it}}} \quad (1)$$

where $\frac{Total\ Taxes\ and\ Fees_{it}}{Green\ Taxes\ and\ Fees_{it}}$ is the annual average of the total taxes and fees paid by the firm, and $\frac{Green\ Taxes\ and\ Fees_{it}}{Green\ Taxes\ and\ Fees_{it}}$ is the annual average of green taxes and fees paid by the firm. As discussed in the institutional background, green taxes and fees in this paper mainly refer to the sewage charges and environmental protection tax enterprises pay. Before the promulgation of the Environmental Protection Tax Law in 2018, green taxes and fees refer to the actual sewage charges paid, while after 2018, they mainly refer to the actual environmental protection tax paid. This normalized metric captures the relative intensity of a firm's green taxes and fees burden compared to the national benchmark, where values greater than 1 indicate a competitive advantage (lower relative green taxes and fees burden) and values below 1 suggest a disadvantage. The greater the competitive intensity of firms' green taxes and fees, the more advantageous the firm's ability to compete in the "race to the bottom" concerning the relative pressures of green taxes and fees relative to other firms in the country.

Figure 3 presents the temporal evolution of green taxes and fees competition (GTFC) among Chinese listed firms from 2007 to 2021. After 2007, the GTFC index demonstrates a clear upward trajectory, rising from below 0.9 in 2008 to approximately 1.1 by 2021. This metric carries important interpretive value: when GTFC exceeds unity ($GTFC > 1$), it indicates that a firm's green taxes and fees burden (measured as the ratio of green taxes and fees to total taxes and fees) is relatively lower than the national average. Conversely, values below unity suggest a comparatively heavier green taxes and fees burden relative to peer firms nationwide. Figure 3 reveals a distinct pattern of fluctuating yet increasing competition intensity in green taxes and fees among Chinese listed companies during 2008–21. This trend suggests these firms have systematically engaged in strategic "race to the bottom" behavior regarding their green taxes and fees burden—a phenomenon that, surprisingly, remains undocumented in the extant literature. Our analysis thus identifies and empirically demonstrates this previously overlooked competitive dynamic in corporate environmental taxation strategies.

3. Theoretical prediction

Based on the fact that Chinese listed companies' behavior is characterized by "race to the bottom" competition in response to the relative pressures of sewage charges and environmental protection tax, in this section we develop a simple theoretical model explaining how corporate green taxes and fees competition indirectly affects total factor productivity changes by changing the degree of energy (mis)allocation.

Our theoretical framework develops along three key dimensions. First, we construct a competitive equilibrium model of energy factor allocation incorporating green taxes and fees distortions, building upon the foundational work of Hsieh and Klenow (2009) and Aoki (2012). Within this framework, we derive the relative distortion coefficient for energy factor prices to systematically examine the linkage between green taxes and fees competition and energy misallocation. Second, employing structural decomposition analysis, we demonstrate that firms' competitive responses to green taxes and fees pressures primarily influence total factor productivity growth through energy misallocation channels. Our model predicts an inverse relationship between green taxes and fees competition intensity and productivity growth, with the mechanism of influence being a worsening energy factor misallocation. Third, we identify three critical moderating variables that condition this relationship: (1) energy factor output elasticity, (2) technological innovation capacity, and (3) output share. (The theoretical derivation and complete mathematical proofs are presented in Appendix A).

4. Empirical strategy

4.1. Baseline specification

To empirically test the causal relationship between the intensity of firms' "race to the bottom" competition against the relative pressure of green taxes and fees and the growth of total factor productivity, we develop the following econometric model:

$$TFPG_{it} = \alpha + \beta GTFPC_{it} + \gamma Z_{it} + \mu_i + \omega_t + \varepsilon_{it} \quad (2)$$

Where i stands for firm and t stands for year. The change in total factor productivity, the dependent variable, is measured as the annual change in the residuals, excluding capital, labor, and energy factors. However, there is a potential endogeneity problem that arises when using the data of Chinese-listed companies for production function estimation. Since the firm decision-maker, i , observes its productivity in time t and can instantly adjust the input mix of factors of production in the next period accordingly, the choice of the firm's future mix of factor inputs will likely depend on the productivity observed in the previous period, resulting in the causality of the factor usage with the magnitude of productivity. Therefore, we used the trans-log form Levinsohn & Petrin (2003) methodology, as modified by Akerberg et al. (2015) to obtain a more precise and reliable value of *Total Factor Productivity Growth*. Akerberg et al. (2015) avoid the problem that labor may not vary independently of nonparametric functions estimated using low-order polynomials by allowing the model to have exogenous, serially correlated, unobserved firm shocks to the price of labor or unobserved firm adjustment costs to labor inputs, as well as by allowing for labor to have more general dynamic effects. Moreover, we also use the firms' intermediate inputs as proxy variables for productivity to effectively solve the endogeneity problem in the production function estimation and thus improve the precision of the analysis of the total factor productivity level. Specifically, our production function estimation takes the form:

$$\begin{aligned} LnY_{it} = & \alpha_0 + \alpha_1 LnK_{it} + \alpha_2 LnL_{it} + \alpha_3 LnE_{it} + \alpha_4 LnK_{it}^2 + \alpha_5 LnL_{it}^2 + \alpha_6 LnE_{it}^2 \\ & + \alpha_7 LnK \times LnL_{it} + \alpha_8 LnK \times LnE_{it} + \alpha_9 LnE \times LnL_{it} + \omega_{it} + \varepsilon_{it} \end{aligned} \quad (3)$$

where LnY_{it} , LnK_{it} , LnL_{it} and LnE_{it} represent the natural logarithmic values of the firm i's value-added, capital stock, labor force quantity, and energy use at time t, respectively. In this case, enterprise value added is measured using the sum of employee compensation, depreciation of assets, taxes, and operating profit; capital stock is expressed in terms of annual net fixed assets; labor force is expressed in terms of the number of employees in a company; and energy use is measured in terms of energy consumption by type converted to uniform standard coal; LnK_{it}^2 , LnL_{it}^2 and LnE_{it}^2 denote the squared term of the logarithm of capital stock, the squared term of the logarithm of the quantity of labor, and the squared term of the logarithm of energy use of firm i at time t, respectively; $LnK \times LnL_{it}$, $LnK \times LnE_{it}$ and $LnE \times LnL_{it}$ denote, respectively, the natural logarithmic interaction terms between the three factors of capital stock, labor quantity, and energy for firm i at time t; α_1 to α_9 denote the coefficients of the effects of each on firm output; ω_{it} is the observed productivity level of firm decision maker i at time t; and ε_{it} is the residual term.

In addition, in Equation (2), we control for a series of firm-level characteristic variables (Z), which mainly contain the influences of firm size, gearing ratio, return on net assets, shareholding concentration, firm growth, dual-job, nature of property rights, loss-making or not, Tobin's Q, and years of listing. Among them, firm size is expressed as the natural logarithm of the firm's total assets; gearing ratio is measured as the ratio of the firm's total liabilities to total assets; return on net assets is expressed as the ratio of the firm's net profit to total assets; shareholding concentration is measured as the proportion of shares held by the first largest shareholder; growth of the firm is expressed through the growth rate of the estimated operating revenues; Tobin's Q is expressed as the ratio of the firm's market capitalization to the value of its total assets minus the value of its net intangible assets and goodwill; and the natural logarithm of the company's current year minus the year of listing plus one is expressed as the year of listing. We use dummy variables to identify whether the chairman and general manager are concurrently appointed, whether it is a state-owned enterprise, and whether it is in the red (loss making or not). In addition, the econometric model adds firm-individual effects μ_i and time-fixed effects ω_t to control for time-trend factors, such as differences in characteristics that do not vary over time at the individual level and the common macro-environment over time, respectively; ε_{it} represents the error term.

Our core explanatory variable, as specified in Equation (1), Green Taxes and Fees Competition (GTFC), is operationalized as follows: $GTFC = (\text{Firm's Green Taxes and fees} / \text{Total Taxes and fees}) / (\text{National Average Green Taxes and fees} / \text{National Average Total Taxes and fees})$. Consistent with theoretical expectations, we predict a negative coefficient for GTFC's impact on total factor productivity (TFP) growth. This implies an inverse relationship whereby intensified "race to the bottom" competition in green taxes and fees corresponds with diminished TFP growth rates. Specifically, as firms increasingly engage in strategic tax competition to reduce their relative green taxes and fees burden, their productivity growth demonstrates measurable decline.

4.2. Instrumental variable

The key explanatory variable of corporate green taxes and fees competition may be endogenous. First, the greater the growth in total factor productivity of an enterprise, the greater the incentive for the enterprise to invest more factor resources, such as capital, labor, and energy, to promote better enterprise development. However, these measures may, to some extent, create a reverse causality by making more substantial competitive incentives for firms to “race to the bottom” in response to the relative pressures of green taxes and fees. In this case, the OLS regression will overestimate the true impact of the competitive intensity of firms' green taxes and fees on total factor productivity growth. Second, although we control for several observable firm-level characteristic variables, other unobservable factors may still be associated with green taxes and fees competition and total factor productivity changes.

To address the endogeneity problem described above, we draw on the constructive ideas of the Bartik shift-share instrumental variable method (Bartik, 1991). First, we take the ratio of green taxes and fees of each industry in each province to the total taxes and fees in each province with a two-period lag as the initial taxes and fees structure. Second, we calculate the growth rate of each firm's competitive intensity of green taxes and fees from 2008 to 2021. Finally, we interact each province's initial taxes and fees structure with the growth rate of firms' green taxes and fees competitive intensity to obtain the Bartik instrumental variable. Specifically, the instrumental variable construction formula is as follows:

$$Bartik\ Instrument = \sum_k Composition_{jk0} \times Competition\ Growth_{it} \quad (4)$$

where $Composition_{jk0}$ is the ratio of the actual green taxes and fees paid by industry k in province j to the total taxes and fees in province j with a two-period lag, and $Competition\ Growth_{it}$ is the growth rate of the competitive intensity of green taxes and fees of firm i in year t. The instrumental variable satisfies the correlation and homogeneity conditions. When the share of green taxes and fees in province j in industry k changes more dramatically across years, the share of corporate taxes and fees in province j, which is initially more dependent on industry k, tends to change more dramatically across years. So, this instrumental variable can strongly predict changes in the proportion of green taxes and fees at the provincial level. In Section 5.3, we empirically test the relevance of this instrumental variable. Second, we use two-period lagged data by province by industry to construct the initial tax and fee relative structure data indicator unaffected by local government policies on sewage and environmental protection tax in subsequent years. Thus, the instrumental variable satisfies the exogeneity requirement.

4.3. Mechanisms

According to our theoretical analysis, the mechanism test mainly consists of two parts: the impact mechanism test and the regulation mechanism test.

Regarding the impact mechanism test, the enterprise green taxes and fees competition indirectly affects the total factor productivity growth by changing the degree of energy factor allocation. Therefore, we construct the following impact mechanism econometric analysis model:

$$Misallocation_{it} = \alpha + \beta GTFC_{it} + \gamma Z_{it} + \mu_i + \omega_t + \varepsilon_{it} \quad (5)$$

In Eq. (5), we mainly utilize the energy factor output elasticity measured by the modified trans-log form Levinsohn & Petrin (2003) method of Akerberg et al. (2015) to indirectly compute the relative degree of distortion of the energy factor for each firm. It was also subjected to a 1% deflator.

Regarding the adjustment mechanism test, the effect of corporate green taxes and fees competition on the magnitude of total factor productivity growth changes with the energy factor output elasticity, the level of technological innovation, and the size of the share of output value. In this regard, we construct the following empirical test model of the regulatory mechanism:

$$TFPG_{it} = \alpha + \beta GTFC_{it} \times Dummy_{it} + \gamma Z_{it} + \mu_i + \omega_t + \varepsilon_{it} \quad (6)$$

Dummy denotes a 0-1 grouped dummy variable for the energy factor output elasticity, technological innovation level, and output share size. Energy factor output elasticity is measured by the trans-log form Levinsohn & Petrin (2003) method modified by Akerberg et al. (2015). The number of invention patents of the firm measures the level of technological innovation. The ratio of firms' value measures the size of the share of output added to the total market output. When the variable's value exceeds the median, it is marked as 1. Otherwise, it is marked as 0. In Section 5.4, we conduct corresponding empirical tests of the moderating effects of energy factor output elasticity, technological innovation level, and output share size on the intensity of firms' green taxes and fees competition.

4.4.Data

We mainly use the data of Chinese A-share listed companies from 2007 to 2021 as our research sample, and the data source is the CSMAR database. During data processing, we performed the following: First, we deleted listed companies with unique treatment markings such as ST, *ST, and PT². Second, missing sample data for key variables such as value added of firms were eliminated. Data on energy consumption were obtained from annual reports of listed companies, social responsibility reports of listed companies, and websites of listed companies. The conversion factor of standard coal for energy consumption refers to the China Energy Statistical Yearbook compiled by the Energy Department of the National Bureau of Statistics of China. The macro data indicators of county-level cities added in the robustness test are from the China County Statistical Yearbook. Table 2 presents the results of descriptive statistics for the main variables. Among them, the mean value of the competitive intensity of listed companies on the relative pressure of green taxes and fees is 0.999, and the standard deviation is 0.9557, indicating that there is a significant difference in the competitive intensity of listed companies on the relative pressure of green taxes and fees.

Table 2
Summary statistics of variables.

Variable	Obs	Mean	Std. dev.	Min	Med	Max
Total Factor Productivity Growth	19944	-0.1011	0.7249	-8.1236	-0.0819	6.6235
Green Taxes and Fees Competition	23848	0.9990	0.9557	0	0.7708	34.3277
Energy Misallocation	23834	1.0653	1.5220	0.0425	0.8879	12.4149
Company Size	23851	22.2809	1.3703	17.6413	22.0680	28.6364

² ST indicates that the stock has financial status and other risk warnings; *ST indicates that the stock has been put on delisting risk warning; PT indicates that the stock has been suspended due to three consecutive years of losses.

Gearing Ratio	23851	0.4298	0.2000	0.0075	0.4263	1.2225
Return on Net Assets	23847	0.1087	2.2749	- 14.5113	0.0750	281.9892
Shareholding Concentration	23851	35.8042	15.0924	0.2900	34.0400	89.9900
Corporate Growth	23829	3.8952	387.2370	-2.9618	0.1172	59411.5500
Dual-job	23851	0.2497	0.4328	0	0	1
Nature of Ownership	23457	0.4219	0.4938	0	0	1
Loss Making or Not	23851	0.0385	0.1925	0	0	1
Tobin's Q	23471	2.0558	1.9536	0.6837	1.6040	122.1895
Years of Listing	23851	2.1593	0.7562	0.6931	2.3025	3.4657

5. Empirical results

5.1. Baseline results

Table 3

Baseline results.

	Dependent variable: Total Factor Productivity Growth		
	(1)	(2)	(3)
Green Taxes and Fees Competition	-0.0268*** (-2.63)	-0.0768*** (-3.07)	-0.1069*** (-8.42)
Company Size			-0.1278*** (-6.93)
Gearing Ratio			0.2327*** (3.04)
Return on Net Assets			0.3424 (1.46)
Shareholding Concentration			0.0011 (1.13)
Corporate Growth			0.0000*** (15.30)
Dual-job			-0.0052 (-0.26)
Nature of Ownership			-0.0039 (-0.10)
Loss Making or Not			-1.2298*** (-16.36)
Tobin's Q			0.0053 (0.83)
Years of Listing			0.0175 (0.65)
Enterprise fixed effect	No	Yes	Yes
Year fixed effect	No	Yes	Yes
_cons	-0.0741*** (-7.62)	-0.0237 (-0.97)	2.7012*** (6.61)
R-squared	0.0013	0.0751	0.1863

Obs	19942	19768	19120
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Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Table 3 presents the baseline regression results at the city level for the clusters estimated by the model.

Columns (1) to (3) report the effects of the intensity of green taxes and fees competition on total factor productivity growth. The difference is that column (1) does not add control variables and does not control for firm-individual and year-fixed effects, column (2) does not add control variables, but controls for firm-individual and year-fixed effects, and column (3) adds the relevant control variables while also controlling for firm-individual and year-fixed effects.

As shown in column (3), the coefficient of the intensity of green taxes and fees competition on total factor productivity growth is negative and significant at the 1 percent statistical level, which is consistent with the hypothesis that firms' "race to the bottom" to reduce the relative pressure of green taxes and fees leads to a loss in productivity. This interaction relationship also holds significant when no control variables are added or when firm-individual and year-fixed effects are not controlled, as shown in columns (1) and (2). In the data sample of listed companies in this paper, the mean value of the intensity of green taxes and fees competition is 0.999. According to the estimation results in column (3), if the intensity of green taxes and fees competition increases by one mean unit, the total factor productivity growth will be reduced by 10.68 percentage points.

5.2. Robustness

To further test the validity of our finding that the intensity of corporate green taxes and fees competition has a significant negative effect on total factor productivity growth, we also need to cope with the interference of other factors such as variable measurement errors, omitted variables, sample selection bias, and so on. that may exist in the benchmark regression on the results of the empirical tests. Specifically, we do the following four robustness tests to try to overcome the influence of other confounding factors:

First, the dependent variable, total factor productivity growth, and the core explanatory variable, green taxes and fees competition, may be subject to measurement error, leading to biased estimates of the impact coefficients. In this regard, we use the total factor productivity change re-measured by the Levinsohn & Petrin (2003) methodology, not modified by Akerberg et al. (2015), as a proxy for the dependent variable to conduct robustness tests. Taking the payable sewage charge or environmental protection tax as a proxy variable for the actual payment of sewage charge or environmental protection tax, we re-measure the competitive intensity of green taxes and fees of enterprises according to Equation (1) and use this as a substitute for the original core explanatory variables for the robustness test.

The results of the robustness test for the measurement error problem are shown in Table 4. Column (1) shows the estimation results with only the dependent variable total factor productivity growth replaced; Column (2) shows the empirical results with both the dependent variable total factor productivity growth and the core explanatory variable green taxes and fees competition intensity replaced; and Column (3) shows the estimation results with only the core explanatory variable green taxes and fees competition intensity replaced. The main results of the robustness tests remain almost unchanged, showing that the baseline regression conclusions are significantly valid.

Second, the current benchmark regression only includes firm-level characteristic variables, which may omit the more important regional-level influences that affect the total factor productivity change. In this regard, on the one hand, we continue to add enterprise-level control variables such as the percentage of independent directors, institutional investors' shareholding, cash flow, tax rebate intensity, and tax incentives, and on the other hand, we also add county-level characteristics such as industrial structure, level of economic development, and intensity of fiscal expenditure, to try to avoid the interference of the potentially omitted variables.

The results of the robustness tests for the omitted variable problem are shown in Table 5. Column (1) shows the estimation results with only the further addition of firm-level characteristic variables; column (2) shows the empirical results with only the further addition of county-level macro variables; and column (3) shows the estimation results with the further addition of both firm and county level dimensional characteristic variables. We find little change in the main results of the robustness tests, which still significantly support the baseline regression results.

Third, to address potential sample selection bias, we implement two complementary approaches. First, we exclude firms located in the four direct-controlled municipalities (Shanghai, Beijing, Tianjin, and Chongqing) from our primary analysis, focusing instead on firms under provincial-level administrations. This exclusion is justified by the distinct governance structure of these municipalities, which benefit from more direct central government oversight, greater policy and financial support, and enhanced administrative autonomy compared to provincial regions - factors that could introduce systematic estimation biases. Second, we conduct regional heterogeneity analysis by stratifying our sample into three geographic groups (Eastern, Central, and Western regions) to examine whether the negative relationship between green taxes and fees competition and total factor productivity growth holds across different regional contexts. This dual approach not only mitigates potential selection bias but also provides important insights into the geographic robustness of our core findings.

The results of the robustness test for the sample selection bias problem are shown in Table 6. Column (1) shows the empirical results after deleting the four largest municipalities; columns (2), (3), and (4) show the estimation results for the data samples from the eastern, central, and western regions, respectively. It can be found that the main regression results of the robustness test still hold significantly.

Fourth, in addition to the effects of measurement error, omitted variables, and sample selection bias mentioned above, there may be a potential confounding problem with the core explanatory variables in this paper: the intensity of green taxes and fees competition is associated with the size of green taxes and fees and the size of total taxes and fees at the same time. Large fluctuations in other taxes or fees in the total tax bill can indirectly lead to fluctuations in the relative pressure on firms' green taxes and fees, leading to biases in the intensity of competition among firms and causing bias in the estimated coefficients. In this regard, according to the analysis in 2.2 Characteristic Facts above, we first choose to delete the sample data of 2020 and 2021, when the total taxes and fees of listed companies fluctuate considerably, to try to avoid the interference of estimation bias caused by the significant fluctuation of the total taxes and fees. Then, according to the different development stages divided by the trend of total taxes and fees change in the 2.2 Characteristic Facts section, the group tests whether the competitive intensity of enterprises' green taxes and fees significantly affects the total factor productivity changes under different trends of total taxes and fees changes.

The results of the robustness test for the potential disturbance problem of the green taxes and fees competitive intensity variable are shown in Table 7. Column (1) is the estimation result of removing the disturbances from the sample of data on the declining trend of total taxes and fees in 2020 and 2021; Columns (2) to (5) show the empirical estimation results for the phase of rising total taxes and

fees from 2008 to 2011, the phase of stable fluctuation of total taxes and fees from 2012 to 2015, the phase of stable fluctuation after the decline of total taxes and fees from 2016 to 2019, and the phase of significant decline of total taxes and fees from 2020 to 2021, respectively. We find that the main regression results of the robustness test are significant, indicating that the baseline regression conclusions of this paper are significantly valid.

5.3. Instrumental variable estimation

Table 8 reports the empirical results of the endogeneity treatment.

As described in section 4.2 of the research design, the intensity of green taxes and fees competition may be endogenous. To address it, we constructed instrumental variables along the Bartik shift-share instrumental variables approach. We conduct multiple sets of empirical estimations further to ensure the credibility of the endogeneity test results. Column (1) in Table 8 shows the results of the two-stage regression without controlling for firms' individual fixed effects; Column (2) shows the results of the two-stage regression on the original baseline regression; Column (3) shows the results of the two-stage regression after replacing the core explanatory variable green tax competition and without controlling for firms' individual fixed effects; and Column (4) shows the results of the two-stage empirical estimation of the core explanatory variable replacement.

Panel B of Table 8 presents the first-stage estimation results. The K-P F statistics in the four regressions are 28.007, 25.546, 27.949, and 25.417, respectively, indicating that the Bartik instrumental variable we constructed is not a weak instrumental variable, which implies that the instrumental variable is effective in predicting changes in the intensity of firms' competition for green taxes and fees. Panel A reports the second-stage regression results. The four regression results show a significant negative relationship between green taxes and fees competitive intensity and total factor productivity growth. Moreover, the impact coefficients of all four sets of second-stage regression results are smaller than the coefficient values estimated by the least squares method, indicating that the OLS regression may significantly overestimate the true impact of green taxes and fees competition on total factor productivity growth. According to the estimation results in Column (2), an increase of one mean unit in the intensity of green taxes and fees competition reduces total factor productivity growth by 9.63 percentage points, which is significantly lower than the intensity of the effect when endogeneity is not addressed.

5.4. Mechanisms

Tables 9 and 10 present the results of the empirical tests of the impact and moderating mechanisms, respectively.

To empirically test whether the energy misallocation impact mechanism is valid and the robustness of its findings, as shown in Table 9, we add control variables, year fixed effects, and individual fixed effects one by one from column (1) to column (5). Panel B shows the first-stage regression results and finds that the K-P F statistics are basically above 25, indicating that the Bartik instrumental variables we constructed are not weak instrumental variables, which can alleviate the problem of overcoming the endogeneity of the firms' green taxes and fees competitive intensity, and effectively predict the change of green taxes and fees competitive intensity. Panel A presents the second-stage regression results. All five regression results indicate a significant positive relationship between green taxes and fees competition and the degree of energy factor misallocation. The estimated residuals measure total factor productivity in this paper in addition to the three significant factors of

capital stock, labor, and energy. When the degree of energy factor misallocation increases, it generally suppresses total factor productivity growth. Therefore, we argue that an increase in the competitive intensity of corporate green taxes and fees indirectly suppresses the magnitude of total factor productivity growth by exacerbating the degree of energy factor misallocation. This is consistent with our theoretical expectations.

To test whether energy factor output elasticity, technological innovation level, and output value share size have a moderating effect on the intensity of green taxes and fees competition, as shown in Table 10, we constructed the cross-multiplier terms of energy factor output elasticity, technological innovation level and output value share size dummy variables and green taxes and fees competition variables. We empirically examined the effect of cross-multiplier terms on total factor productivity growth. Column (1) shows the results of the moderating effect of the size of output share on the intensity of green taxes and fees competition; column (2) shows the moderating effect of the level of technological innovation on the intensity of green taxes and fees competition; and column (3) shows the results of the moderating effect of the elasticity of the output of the energy factor on the intensity of green taxes and fees competition.

Panel B in Table 10 shows the results of the first stage regression with K-P F statistics values of 10.762, 24.993, and 47.326, respectively, suggesting that the constructed Bartik instrumental variables are effective in overcoming the endogeneity problem that exists with the core explanatory variables. Panel A presents the results of the second-stage regressions for the three sets of tests of the moderating mechanism. All three sets of empirical estimation results show that the moderating variables have a negative constraint effect on the power of green taxes and fees competition to affect total factor productivity growth. The negative impact of the green taxes and fees competition intensity variable on total factor productivity growth is more significant when the listed company's market share of output value, technological innovation level, and energy output elasticity is relatively high. This suggests that listed companies with relatively higher output shares, technological innovation levels, and energy output elasticities have more substantial incentives to “race to the bottom” compete for the relative pressure of green taxes and fees, negatively impacting total factor productivity growth.

In addition, building upon our institutional analysis highlighting the distinct characteristics of sewage charges and environmental protection taxes (stronger environmental regulation), we investigate an important extension: how do these differing institutional arrangements influence the productivity impacts of green taxes and fees competition? To examine this question, we further set up an econometric model to empirically test the differential impacts of the change from sewage charge to environmental protection tax. Our analysis reveals that the policy transition exacerbated the negative productivity effects of green taxes and fees competition, particularly for high-polluting firms. The strengthened regulatory stringency under the environmental protection tax regime appears to have intensified firms' competitive responses to green tax pressures, resulting in more pronounced productivity declines. This effect is most salient for state-owned enterprises and firms engaged in greenwashing practices, while being partially mitigated for high-technology firms (see Appendix B for complete methodological details and empirical results).

6. Conclusions

Over the past few decades, numerous federal states have intensified fiscal decentralization to leverage local information advantages and enhance fiscal incentives (Shah, 2006; Oates, 2008; Weingast, 2009; Gadenne and Singhal, 2014). However, this trend toward greater decentralization has amplified inter-jurisdictional tax competition, potentially leading to a “race to the bottom” in tax rates

(Oates, 1972; Oates and Schwab, 1988; Wilson, 1999; Dijkstra and Fredriksson, 2010; Janeba and Wilson, 2011; Lyytikäinen, 2012; Janeba and Osterloh, 2013; Buettner and Poehnlein, 2024).

Building on these theoretical foundations, we identify a novel “race to the bottom” phenomenon in corporate green taxes and fees driven by structural distortions within tax systems. This finding provides new empirical evidence highlighting the limitations of decentralized governance without checks and balances for subnational tax competition processes. Our analysis reveals that firms exhibit heterogeneous responses to different tax burdens, particularly in their sensitivity to green and conventional taxes and fees. Green taxes and fees, designed to internalize negative externalities, create distinct competitive dynamics compared to other fiscal instruments. Consequently, when firms strategically respond to differential tax pressures across tax categories, traditional tax competition evolves into competition over tax structure composition.

In this regard, we focus on the issue of green taxes and fees competition and their efficiency implications, a common concern of fiscal and environmental federalism. Based on the constructed theoretical model of energy factor allocation that includes the distortionary coefficients of green taxes and fees, we predict that the total factor productivity growth of firms will decrease as the intensity of their competition against the relative pressures of green taxes and fees increases in a “race to the bottom” manner. Using data on listed companies in China, we find a robust negative correlation between the “race to the bottom” competitive intensity of green taxes and fees pressure and total factor productivity growth. In addition, we find that corporate green taxes and fees pressure “race to the bottom” competition indirectly inhibits total factor productivity growth, mainly by increasing the degree of energy factor misallocation. An intrinsic mechanism by which green taxes and fees competition inhibits efficiency growth is that the intensity of firms’ “race to the bottom” for green taxes and fees under environmental federalism is higher when firms’ energy output elasticity, level of technological innovation, and share of output are higher. Stronger environmental regulatory measures, while helping to overcome the fundamental problems of insufficient enforcement rigidity and excessive government intervention in the sewage charging system, can force state-owned high-polluting enterprises and greenwashing high-polluting enterprises to develop stronger rent-seeking profit motives towards budgetary constraints and false environmental propaganda, respectively, and distort to a certain extent the technological greening transformation behaviors of high-polluting enterprises with high technology. Our findings provide empirical evidence for decentralized countries to reverse the competitive behavior of green taxes and fees, improve the decentralization of green taxes and fees, and design the enforcement intensity of environmental policies.

Recent initiatives by international organizations, including the United Nations Environment Programme and the World Bank, have advocated for stronger environmental regulations to enhance global environmental protection efforts. However, our study shows that excessive regulatory stringency may inadvertently intensify strategic profit-seeking behaviors among local firms. We provide novel empirical evidence demonstrating how firms under decentralized systems prioritize reducing green taxes and fees burdens relative to other taxes and fees when faced with stringent environmental regulations. This competitive response manifests itself as a “race to the bottom” in green taxes and fees, potentially leading to resource misallocation and efficiency losses. Our findings suggest that while strengthening environmental regulations is crucial for addressing global environmental challenges, policymakers must carefully calibrate regulatory intensity to balance environmental objectives with economic efficiency in decentralized governance systems.

Table 4

Robustness check: replacement of variables.

	Dependent variable: Total Factor Productivity Growth II		Dependent variable: Total Factor Productivity Growth
	(1)	(2)	(3)
Green Taxes and Fees Competition	-0.1067*** (-8.51)		
Green Taxes and Fees Competition II		-0.1067*** (-8.51)	-0.1068*** (-8.41)
Control Variables	Yes	Yes	Yes
Enterprise Fixed Effect	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes
_cons	0.4329 (1.18)	0.4330 (1.18)	2.7013*** (6.62)
R-squared	0.2286	0.2286	0.1863
Obs	19120	19120	19120

Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Table 5

Robustness check: add control variables.

	Dependent variable: Total Factor Productivity Growth		
	(1)	(2)	(3)
Green Taxes and Fees Competition	-0.1339*** (-7.98)	-0.1047*** (-8.45)	-0.1322*** (-7.77)
Percentage of Independent Directors	-0.0026 (-1.35)		-0.0032 (-1.59)
Institutional Investor Shares	0.0012 (1.62)		0.0010 (1.39)
Cash Flow	1.2689*** (7.41)		1.2874*** (7.03)
Tax Rebate Intensity	0.0054 (0.71)		0.0016 (0.16)
Tax Incentives	-0.1149* (-1.81)		-0.1232* (-1.72)
Industrial Structure		0.0028 (1.45)	0.0030 (1.60)
Economic Development Level		0.0184 (0.47)	0.0141 (-0.31)
Fiscal Expenditure Intensity		0.0191 (0.31)	-0.0169 (-0.34)
Control Variables	Yes	Yes	Yes
Enterprise Fixed Effect	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes

_cons	2.8433*** (6.91)	2.1056*** (3.18)	2.3283*** (3.29)
R-squared	0.1999	0.1952	0.2080
Obs	16845	17390	15492

Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Table 6

Robustness check: replacement of data samples.

	Dependent variable: Total Factor Productivity Growth			
	(1)	(2)	(3)	(4)
Green Taxes and Fees Competition	-0.1198*** (-5.94)	-0.1097*** (-8.17)	-0.1539*** (-4.23)	-0.1068*** (-3.44)
Control Variables	Yes	Yes	Yes	Yes
Enterprise Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
_cons	2.7458*** (6.13)	1.9515*** (4.26)	3.4017*** (4.73)	3.2709** (2.65)
R-squared	0.1941	0.1920	0.2482	0.1786
Obs	15666	13064	3451	2596

Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Table 7

Robustness check: Exclusion of changes in total taxes and fees

	Dependent variable: Total Factor Productivity Growth				
	(1)	(2)	(3)	(4)	(5)
Green Taxes and Fees Competition	- 0.1253*** (-6.19)	- 0.2919*** (-4.00)	- 0.2273*** (-3.60)	- 0.1045*** (-2.75)	- 0.1325** (-2.15)
Control Variables	Yes	Yes	Yes	Yes	Yes
Enterprise Fixed Effect	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes
_cons	3.0669*** (5.82)	0.3473 (0.16)	0.9340 (0.51)	4.6327** (2.01)	9.9749** (2.21)
R-squared	0.1860	0.3252	0.3287	0.3595	0.6025
Obs	14708	3150	4958	6316	3868

Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Table 8

Instrumental variable estimation.

Panel A: Second stage results				
Dependent variable: Total Factor Productivity Growth				
	(1)	(2)	(3)	(4)
Green Taxes and Fees Competition	-0.0674** (-2.18)	-0.0964*** (-2.62)		
Green Taxes and Fees Competition II			-0.0675** (-2.18)	-0.0965*** (-2.62)
Control Variables	Yes	Yes	Yes	Yes
Enterprise Fixed Effect	No	Yes	No	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
R-squared	0.1017	0.1218	0.1017	0.1218
Obs	16258	16120	16258	16120
Panel B: First-stage results				
	Green Taxes and Fees Competition (1)	Green Taxes and Fees Competition (2)	Green Taxes and Fees Competition II (3)	Green Taxes and Fees Competition II (4)
Bartik IV	3.4807*** (5.29)	2.8870*** (5.05)	3.4775*** (5.29)	2.8839*** (5.04)
Kleibergen-Paap rk Wald F statistic	28.007	25.546	27.949	25.417

Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Table 9

Influence Mechanism Test Results

Panel A: Second stage results					
Dependent variable: Energy Misallocation					
	(1)	(2)	(3)	(4)	(5)
Green Taxes and Fees Competition	0.1838** (2.04)	0.1496** (2.07)	0.1476** (2.01)	0.0791** (2.47)	0.0752** (2.33)
Control Variables	No	Yes	Yes	Yes	Yes
Enterprise Fixed Effect	No	No	No	Yes	Yes
Year Fixed Effect	No	No	Yes	No	Yes
R-squared	0.0042	0.2711	0.2745	0.0293	0.0191
Obs	16825	16265	16265	16127	16127
Panel B: First-stage results					
	Green Taxes and Fees Competition (1)	Green Taxes and Fees Competition (2)	Green Taxes and Fees Competition (3)	Green Taxes and Fees Competition (4)	Green Taxes and Fees Competition (5)
Bartik IV	3.6758*** (5.90)	3.5063*** (5.31)	3.4882*** (5.28)	2.9108*** (5.09)	2.8887*** (5.06)
Kleibergen-Paap rk Wald F statistic	34.794	28.151	27.849	25.869	25.587

Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Table 10
Regulatory Mechanisms Test Results

	Dependent variable: Total Factor Productivity Growth		
	(1)	(2)	(3)
Panel A: Second stage results			
Green Taxes and Fees Competition × Output Value Share Dummy	-0.1732** (-2.48)		
Green Taxes and Fees Competition × Technological Innovation Dummy		-0.1009*** (-2.66)	
Green Taxes and Fees Competition × Energy Output Elasticity Dummy			-0.2067** (-2.18)
Control Variables	Yes	Yes	Yes
Enterprise Fixed Effect	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes
R-squared	0.0921	0.1199	0.1052
Obs	16120	16120	16120
Panel B: First-stage results			
	Green Taxes and Fees Competition * Dummy		
	(1)	(2)	(3)
Bartik IV	1.6060*** (3.28)	2.7575*** (5.00)	1.3459*** (6.88)
Kleibergen-Paap rk Wald F statistic	10.762	24.993	47.326

Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Appendix A Theoretical model

1. Basic settings

1.1 Firm production

Consider a multisectoral production system containing N sectors. Assume that all firms in the same sector have the same production function so that each sector can be viewed as a representative firm engaged in production and business activities. Government agencies are not directly involved in enterprises' production and operation activities; they only macro-regulate the degree of allocation of various types of resources by enterprises through tax and fee covenants. We further assume that all firms use three resources for production: capital stock K , labor L , and energy E , and all firms are assumed to be price takers. There are differences in the allocation of resources such as capital, labor, and energy across sectors, and thus, sectors with different production behaviors can be assumed to have different production functions. The representative firms in each sector have different levels of resource misallocation and technical efficiency. The production function of the representative firm in sector i is assumed to be:

$$Y_i = A_i K_i^{\alpha_i} L_i^{\beta_i} E_i^{\gamma_i} \quad (A1)$$

In equation (A1), Y denotes the firm's output, and K , L , and E represent the amount of capital, labor, and energy input by the firm, respectively. The parameters α_i , β_i and γ_i denote the proportion of the contribution of capital stock, labor, and energy factors to the enterprise's output, respectively. A_i denotes the total factor productivity of the enterprise in addition to capital, labor, and energy inputs. The production function of the representative firm is assumed to be scale reward invariant, i.e., to have the following relationship: $\alpha_i + \beta_i + \gamma_i = 1$.

1.2 Aggregate production function

In this paper, we refer to the treatment of Hsieh and Klenow (2009) and assume that the economy's total economic output is also a function of the Cobb-Douglas form: $Y = Y(Y_1, \dots, Y_N) = \prod_{i=1}^N Y_i^{\theta_i}$, where θ_i denotes the output elasticity of economic output θ_i and $\sum_{i=1}^N \theta_i = 1$. The economy-wide revenue maximization problem is then: $\max R = PY - \sum_{i=1}^N p_i Y_i = PY(Y_1, \dots, Y_N) - \sum_{i=1}^N p_i Y_i$, where P is the price of the overall economic output, and p_i is the price of the firm's economic output. The first-order condition is obtained by solving the economy-wide revenue maximization problem: $\frac{\partial R}{\partial Y_i} = P \frac{\partial Y}{\partial Y_i} - p_i = 0$, i.e., $\frac{\partial Y}{\partial Y_i} = \frac{p_i}{P}$. Assuming that overall economic output is the benchmark price, there are $P=1$. According to the constant returns to scale property of the output function and Euler's theorem, the economic output of the economy as a whole is equal to the linear sum of the firms' outputs: $Y = \sum_{i=1}^N p_i Y_i$. Since $\frac{\partial Y}{\partial Y_i} = \theta_i \frac{Y}{Y_i}$, the share of economic output is $\theta_i = \frac{p_i Y_i}{Y}$.

1.3 Additional settings

Further, it is assumed that the total supplies of capital, labor, and energy factors in the firm's production process are exogenously given with the constraints: $\sum_{i=1}^N K_i = K$, $\sum_{i=1}^N L_i = L$ and $\sum_{i=1}^N E_i = E$. In addition, we assume that there are no intertemporal choice behavioral effects of capital depreciation, sunk costs, labor entry-exit and unemployment, government public savings, and inflationary pressures.

2. Green taxes and fees competition and energy misallocation

2.1 The profit maximization problem

Further drawing on Aoki (2012), assume that of the three resources of the representative firm, only the price of the energy factor is distorted, and that the distortion is mainly caused and captured by the green taxes and fees in the form of an ad valorem tax “deed”. The capital, labor, and energy prices faced by the representative firm i are denoted as rK_i , wL_i , and $(1 + \tau_{Ei})\delta E_i$. Where r , w , and δ are the price level of capital rent, labor wages, and energy consumption under competitive conditions, respectively; τ_{Yi} assumed to be the price distortion of the products of the representative enterprise participating in the market competition, and τ_{Ei} denoted the price distortion of the representative enterprise's energy factors, respectively, as the “deed.”

At this point, based on the above basic assumptions, the profit maximization formula for the representative firm is as follows:

$$\max_{K_i, L_i, E_i} \pi_i = \max_{K_i, L_i, E_i} \left\{ (1 - \tau_{Yi}) p_i Y_i - rK_i - wL_i - (1 + \tau_{Ei}) \delta E_i - C_i \right\} \quad (A2)$$

In Eq. (A2), p_i is the market price of the product faced by the enterprise. Building upon the economic definition of green taxes and fees, including their tax base and effective tax rate, we further model the ad valorem distortion coefficients as deriving from two distinct sources: (1) the aggregate burden of corporate taxes and fees, and (2) environmental protection taxes (or sewage fees) specifically. These coefficients capture the price distortions imposed on both final products and energy inputs for a representative firm. Specifically, the product price distortion index τ_{Yi} is defined as the change in the payment rate of total corporate taxes and charges levied from firms to participate in the competitive production activities in the marketplace. The energy factor price distortion index τ_{Ei} is defined as the change in the payment rate of environmental protection tax levied on firms based on the level of pollution (or the change in the rate of payment of sewage charges). C_i represents the fixed cost of production of a representative firm. We believe that profit-maximizing enterprises when using energy factors for production and business activities, will consider not only the green taxes and fees burden of energy factors but also the total taxes and fees pressure in the final product revenue.

By solving this profit maximization problem, the first-order condition for energy factor allocation is obtained as:

$$\frac{\gamma_i (1 - \tau_{Yi}) p_i Y_i}{E_i} = (1 + \tau_{Ei}) \delta \quad (A3)$$

2.2 Competitive equilibrium solutions for energy allocation

Based on the total factor productivity level A_i of N enterprises, the total taxes and fees distortion ratio τ_{Yi} and the environmental protection tax (sewage charge) distortion ratio τ_{Li} faced by enterprises, and the total resources of the whole economy, the competitive equilibrium solution of resource allocation with the effect of green taxes and fees distortion will satisfy the first-order conditions of enterprise optimization, the invariance of the scale reward of the sum function and resource constraints, and so on. In this case, the competitive equilibrium solution of energy factor allocation with green taxes and fees distortion can be found as follows:

$$E_i = \frac{\gamma_i(1-\tau_{Yi})p_iY_i}{(1+\tau_{Ei})\delta} E = \frac{\gamma_i(1-\tau_{Yi})\theta_i}{1+\tau_{Ei}} E \quad (A4)$$

2.3 Green taxes and fees competition and the degree of energy misallocation

Further, it is assumed $\tilde{\gamma} = \sum_{i=1}^N \gamma_i \theta_i$ to be the weighted average of the output elasticities of firms'

energy factors. It is also assumed $\lambda_{YEi} = \frac{1-\tau_{Yi}}{1+\tau_{Ei}}$ to be the absolute distortion coefficient of the interaction

of the firm's energy factor with the product market due to structural changes in the ratio of green taxes and fees to total taxes and fees. The coefficient of absolute distortion portrays the price markup that firms face on the undistorted price of the energy factor and captures information on the absolute value of the cost of using the energy factor. When the distortionary ‘‘covenants’’ faced by firms in their use of energy are the total corporate tax payment rate $\tau_{Yi} = 0$ and the environmental protection tax (sewage charge) payment rate $\tau_{Ei} = 0$, then we have $\lambda_{YEi} = 1$, indicating that there is no distortion in energy prices. In addition, $\tilde{\lambda}_{YEi}$ is assumed to be the coefficient of relative distortion of energy due to the relative movement of structural distortions in green taxes and fees among firms versus total taxes and fees. Accordingly, adjusting equation (A4), there is a relationship between the energy factor allocation and the energy factor distortion coefficient:

$$E_i = \frac{\gamma_i \theta_i}{\tilde{\gamma}} \tilde{\lambda}_{YEi} E = \frac{\gamma_i \theta_i}{\tilde{\gamma}} \frac{\lambda_{YEi}}{\sum_{i=1}^N \frac{\gamma_i \theta_i \lambda_{YEi}}{\tilde{\gamma}}} E \quad (A5)$$

At this point, in competitive equilibrium, the relative distortion coefficient of the energy factor is:

$$\tilde{\lambda}_{YEi} = \frac{E_i/E}{\gamma_i \theta_i / \tilde{\gamma}} = \frac{\lambda_{YEi}}{\sum_{i=1}^N \frac{\gamma_i \theta_i \lambda_{YEi}}{\tilde{\gamma}}} = \frac{1-\tau_{Yi}}{1+\tau_{Ei}} \quad (A6)$$

Equation (A6) represents the coefficient of relative distortion of energy factor prices as affected by the structural relative change between corporate green taxes and fees and total taxes and fees. That is, the coefficient of relative distortion of energy prices, $\tilde{\lambda}_{YEi}$, is measured by the ratio of the weighted average of the total taxes and fees burden rates to the green taxes and fees burden rates between firm i and the economy as a whole. The coefficient of relative distortion reflects the relative position of

firms in terms of energy price distortions compared to the weighted average of the economy. It captures relative information on the cost of energy use. If the coefficient of relative energy price distortion $\lambda_{YEi} > 1$, then firms' energy use costs are relatively low relative to the economy as a whole, and firms are over-allocating energy factors.

Further, suppose we assume that $\frac{1 - \bar{\tau}_{Yi}}{1 + \bar{\tau}_{Ei}}$ is the mean level of the relative change in the structure of the ratio of payment between total taxes and fees and green taxes and fees for the economy as a whole, we can derive the following relationship between the role of the coefficient of relative distortion of the energy factor and the degree of corporate competition for green taxes and fees:

$$\lambda_{YEi} = \frac{E_i / E}{\gamma_i \theta_i / \gamma} \propto \frac{\frac{1 - \bar{\tau}_{Yi}}{1 + \bar{\tau}_{Ei}}}{\frac{1 - \bar{\tau}_{Yi}}{1 + \bar{\tau}_{Ei}}} \quad (A7)$$

In Eq. (A7), based on the characteristic facts section above, we know that local governments have incentives to relax the standards for sewage charges and environmental protection tax in exchange for short-term economic growth gains, which provides room for firms to act strategically to change the relative tax burden of sewage charges or environmental protection tax, i.e., they can change the ratio of green taxes and fees to the total taxes and fees. Therefore, we denote the competitive intensity of

green taxes and fees of firm i by $\frac{1 - \bar{\tau}_{Yi}}{1 + \bar{\tau}_{Ei}}$, which portrays the “race to the bottom” competitive

behavior. At this point, the relative distortion factor of firms' energy consumption can be expressed by the ratio of the quantity of firm i energy consumption to the overall total energy consumption, and the ratio of the amount of firm i energy consumption to the overall total energy consumption in the theoretically efficient allocation, is proportional to the intensity of firms' competition for green taxes and fees. The relative energy distortion coefficient between firms is influenced by the intensity of the “race to the bottom” competition in response to the relative pressure of green taxes and fees. When the actual rate of payment of environmental protection tax (sewage charge) by enterprises rises by a small amount relative to the national average, the intensity of competition for green taxes and fees pressure increases, leading to a rise in the misallocation of energy factors.

3. Green taxes and fees competition, energy misallocation, and total factor productivity growth

3.1 Decomposition of total factor productivity changes

This section completes analyzing the role of the degree of energy misallocation in changes in total factor productivity from a comparative static perspective. Since business statistics are usually aggregated at the end of the year, the difference between the period $t - 1$ and the period t due to the change in time t can be expressed as a difference operator Δt . Accordingly, the natural logarithmic deformation of the output function, with the help of Taylor's first-order expansion, combined with the two-period variation production function and the resource allocation model, we have that the change in economic output $\Delta \ln Y_t$ can be decomposed and transformed into the change in total factor productivity as:

$$\Delta TFP_t = \sum_{i=1}^N \theta_{it} \Delta \ln \left[A_{it} \cdot (\lambda_{YKi}^{\infty})^{\alpha_{it}} (\lambda_{YLi}^{\infty})^{\beta_{it}} (\lambda_{YEi}^{\infty})^{\gamma_{it}} \right] + \psi$$

$$\psi = \sum_{i=1}^N \theta_{it} \left[(\alpha_{it} \Delta \ln \alpha_{it} + \beta_{it} \Delta \ln \beta_{it} + \gamma_{it} \Delta \ln \gamma_{it}) - (\alpha_{it} \Delta \ln \tilde{\alpha}_t + \beta_{it} \Delta \ln \tilde{\beta}_t + \gamma_{it} \Delta \ln \tilde{\gamma}_t) \right]$$
(A8)

It can be seen that changes in economy-wide total factor productivity arise mainly from the role of technological innovation, resource misallocation, and output share. The parameter ψ represents other factors, such as the change in the share of output. When aggregated to the representative firm level, this can mean that the degree of capital, labor, and energy mismatches of firms can affect total factor productivity changes.

3.2 Green taxes and fees competition, energy misallocation, and total factor productivity growth

Bringing Eq. (A7) into Eq. (A8), a mechanism can be proposed for the role of the “race to the bottom” competitive intensity of firms' relative pressure on green taxes and fees in influencing changes in total factor productivity:

$$\Delta TFP_t = \sum_{i=1}^N \theta_{it} \Delta \ln \left[A_{it} \cdot (\lambda_{YKi}^{\infty})^{\alpha_{it}} (\lambda_{YLi}^{\infty})^{\beta_{it}} \left(\frac{1 - \tau_{Yi}}{1 + \tau_{Ei}} \right)^{\gamma_{it}} \right] + \psi$$
(A9)

According to equation (A9), the “race to the bottom” competitive intensity of the relative pressure of green taxes and fees of enterprises can affect the magnitude of total factor productivity changes.

The partial derivatives of equation (A9) can be obtained $\frac{\partial \Delta TFP_t}{\partial \tau_E} < 0$. It shows that with the increase

of corporate green taxes and fees, the intensity of enterprises' “race to the bottom” competition against the relative pressure of green taxes and fees increases, which dampens the growth of total factor productivity. Moreover, it can also be found that the extent of the impact of corporate green taxes and fees competition behavior on total factor productivity growth changes with the energy factor output elasticity, the level of technological innovation, and the difference in output shares. In addition, combined with equation (A7), it can be seen that corporate green taxes and fees competition mainly affect total factor productivity changes indirectly through the energy misallocation.

Appendix B The heterogeneous impact of changing sewage charge to environmental protection tax

Existing literature suggests that the state is more willing to subsidize and invest in state-owned enterprises, among other things (Kornai, 1986; Dewatripont and Maskin, 1995), capital markets may be more likely to give positive feedback to green technology firms (Bolton and Kacperczyk, 2021; Flammer, 2021; Stroebel and Wurgler, 2021), and investors are more inclined to hold stocks with good ESG performance (Pástor et al., 2021; Avramov et al., 2022). Corporate property rights attributes, high-tech capabilities, and ESG performance, which affect the subjective expectation judgment of investment subjects, may distort the effect of environmental policy implementation. Therefore, we mainly focus on three aspects of enterprise property rights attributes, high-tech capabilities, and the degree of greenwashing to further explore the heterogeneous effects on total factor productivity growth of enterprises' competitive behavior on the relative pressure of environmental protection tax after the implementation of the policy changing the sewage charge to the environmental protection tax.

1. Research design

To empirically test the effect of green taxes and fees' competitive behavior on total factor productivity growth after the sewage fee to environmental protection tax policy, we establish the following econometric model:

$$TFPG_{it} = \alpha + \beta GTFC_{it} \times Treatpost_{it} + \gamma Z_{it} + \mu_i + \omega_t + \varepsilon_{it} \quad (B1)$$

Where *Treatpost* is the cross-multiplier between the dummy variable for whether the individual belongs to the treatment group and the dummy variable for whether the time is after policy implementation, high-polluting firms are the treatment group, with *Treat* marked as 1; *Post* marked as 1 after the change from sewage charges to environmental protection tax in 2018. *GTFC* is cross-multiplied with *Treatpost* as an intensity variable. At this point, the magnitude of the coefficient β is our primary metric of interest.

To analyze the heterogeneous effects of green taxes and fees competition on total factor productivity growth after the change of sewage charge to environmental protection tax policy, we further constructed the following econometric model:

$$TFPG_{it} = \alpha + \beta GTFC_{it} \times Treatpost_{it} \times Dummy_{it} + \gamma Z_{it} + \mu_i + \omega_t + \varepsilon_{it} \quad (B2)$$

In the formula, the *Dummy* variable contains three prominent cases of heterogeneity: first, whether the firm is state-controlled, which is marked as 1 if it is; second, whether the firm is a high-technology firm, which is marked as 1 if it is; and third, whether the firm engages in greenwashing behavior, which is marked as 1 if it does. Moreover, cross-multiply this *Dummy* variable with the core explanatory and policy treatment variables. The magnitude of the coefficient β captures the heterogeneous effect of green taxes and fees competition on total factor productivity growth under different conditions.

2. Empirical results

Based on Eq. (B1) and Eq. (B2), after implementing the policy change of from the sewage charge to the environmental protection tax, the heterogeneous impacts of green taxes and fees competition on total factor productivity growth are shown in Table B1.

Table B1**Heterogeneous Impact of Changing Sewage Charges to Environmental Protection Taxes**

		Dependent variable: Total Factor Productivity Growth
<hr/>		
Panel A: Green Taxes and Fees Competition × Treatpost		
0		-0.1066*** (-8.40)
1		-0.1179*** (-5.74)
<hr/>		
Panel B: Green Taxes and Fees Competition × Treatpost × State-controlled Dummy		
0		-0.1068*** (-8.43)
1		-0.1100*** (-4.42)
<hr/>		
Panel C: Green Taxes and Fees Competition × Treatpost × High-tech Dummy		
0		-0.1071*** (-8.41)
1		-0.0867*** (-2.91)
<hr/>		
Panel D: Green Taxes and Fees Competition × Treatpost × Greenwashing Dummy		
0		-0.1663*** (-4.59)
1		-0.2202*** (-4.01)

Note: T-values corresponding to robust standard errors for clustering at the city level are in parentheses; *** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level; Both added control variables, enterprise fixed effect, and year fixed effect; Observations from Panel A to Panel C are 19120, while Panel D is 3550.

Panel A results show that after the implementation of the policy change, the negative effect of the “race to the bottom” competitive intensity of high-polluting enterprises on the relative pressure of environmental protection tax on the growth of total factor productivity is even more significant. It shows that after the implementation of the policy change, the more assertive environmental regulatory policy for high-polluting enterprises led to a stronger competitive incentive for high-polluting enterprises to compete against the relative pressure of green taxes and fees, forcing the growth of total factor productivity to decline relatively more sharply.

Panel B empirical results show that after implementing the policy change from sewage charges to environmental protection tax, the competitive intensity of the relative pressure of environmental protection tax on the high-polluting enterprises in the state-owned enterprises has a more significant negative impact on the growth of total factor productivity. The results in Panel C indicate that after the implementation of the policy change, the competitive intensity of the relative pressure of environmental protection tax on high-polluting enterprises in high-tech enterprises has a relatively small negative effect on the growth of total factor productivity. Panel D results indicate that the competitive intensity of the relative pressure of environmental protection tax on high-polluting enterprises with greenwashing behavior has a more significant adverse effect on total factor productivity growth after the policy implementation. The three sets of heterogeneous empirical results

show that both state-owned property rights attributes and greenwashing behavior aggravate the competitive intensity of the relative tax pressure on environmental protection tax. At the same time, enterprise high-technology characteristics help to mitigate the competitive intensity of the relative tax pressure on environmental protection tax.

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