Environmental Target Responsibility System, Governance, and Economic Growth

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Abstract: *This paper develops an economic growth model incorporating China's Environmental Target Responsibility System (ETRS) to analyze its impact on both economic growth and social welfare. We find that the ETRS's effect on economic growth is complex, resulting from the interplay of three key factors: its potential to improve environmental quality, its potential dampening effect on total factor productivity (TFP), and its influence on local government spending on environmental governance. A balanced ETRS can improve environmental quality, promote technological innovation, and enhance social welfare. However, excessively stringent targets and overly emphasized responsibility may lead to declines in both economic growth and social welfare. From the perspective of balancing economic growth and social welfare, we find that the ETRS that maximizes economic growth is less stringent than the ETRS that maximizes social welfare. Crucially, the economic growth cost of shifting from a growth-maximizing to a welfare-maximizing ETRS is minimal. In other words, significant improvements in environmental quality and public well-being can be achieved without substantially sacrificing economic dynamism. This paper attempts to model China's unique environmental target assessment system within the framework of endogenous growth theory, offering a new perspective for understanding the dynamic relationship between economic growth and environmental quality in China.*

Keywords: *Environmental target responsibility system (ETRS); environmental governance; economic growth; social welfare; local government*

JEL Classification Codes: H23, H70, O41

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1. Introduction

Since China's reform and opening-up started in 1978, local governments have played a central role in driving economic growth, significantly boosting productivity and alleviating the contradiction between the people's ever-increasing material and cultural needs and the lagging social production. With China's entry into a new era of socialism with Chinese characteristics, the principal social contradiction has shifted to one between unbalanced and insufficient development and the people's ever-growing

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aspirations for a better life. The people's need for a beautiful ecological environment has become a key aspect of this contradiction, and the development of an ecological civilization has been enshrined in both the Chinese Constitution and the Constitution of the Communist Party of China (CPC). The 20th CPC National Congress underscored that Chinese modernization must be defined by harmonious coexistence between humanity and nature. Building a fully modern socialist country requires a fundamental commitment to respecting, protecting, and living in harmony with nature. It is essential to firmly establish and practice the concept that "lucid waters and lush mountains are invaluable assets", and to plan development from the perspective of harmonious coexistence between humans and nature.

China's approach to ecological civilization has gradually shifted from focusing on controlling the total emissions of major pollutants to environmental quality constraints. The country is now at a critical stage where reducing carbon emissions is the key strategic direction with an aim to synergize pollution reduction and carbon mitigation. This shift also seeks to accelerate the comprehensive green transformation of economic and social development, and drive a fundamental improvement in environmental quality. Environmental issues are not only vital for sustainable economic development but also central to people's livelihoods and a matter of significant political importance. China faces a significant theoretical and practical challenge in effectively formulating and implementing environmental policies that achieve green development and harmonize economic growth with ecological civilization.

China's pursuit of an "ecological civilization" is currently a top-down endeavor, with the central government setting strategic priorities and local governments responsible for implementation. Local officials are thus key enforcers of ecological policies on the ground. However, this approach faces a fundamental tension, as highlighted by the Environmental Kuznets Curve: early-stage economic development often clashes with environmental protection, making the balance between growth and sustainability a critical challenge. The COVID-19 pandemic and escalating geopolitical tensions have complicated the existing uncertainties, increasing the pressure on both central and local governments to prioritize economic stability and development. This raises a crucial question: how can the central government incentivize local governments to strengthen environmental governance amid these competing pressures? To explore this dynamic, this paper develops an environmental decision-making model incorporating environmental target assessments, political incentives, and the "one-ballot veto" system that holds officials accountable by allowing higher authorities to veto their performance if they fail to meet environmental targets. This model examines how the ETRS influences local government behavior and its broader impact on economic growth and social welfare.

Existing research has shown that China's distinctive approach to managing economic growth targets has been a significant driver of its rapid economic expansion. The central government sets ambitious growth objectives, which are then cascaded down to local governments. Motivated by performance evaluations, political promotions, and economic rewards, local governments mobilize all available resources to foster economic development (Li & Xu, 2021). While China established an ETRS relatively early, its initial effectiveness was hampered by technical challenges in measuring environmental performance and the aspirational nature of many environmental goals. Lacking robust incentives and accountability, the system failed to sufficiently engage local officials in meaningful environmental governance, creating a paradox: central government emphasis on environmental protection versus local governments' "superficial implementation", prioritizing economic growth. However, as China addressed shifts in its principal social contradictions and deepened its commitment to ecological civilization, the central government recognized the shortcomings of existing performance evaluations. Consequently, during the 11th Five-Year Plan (2006-2010), it integrated environmental targets into local performance evaluations, making them legally binding. This imposed constraints on local officials through the "one-ballot veto" system—effectively enforcing environmental "tightening measures"—while also providing incentives through the competitive performance evaluation model, encouraging greater resource allocation toward environmental protection. These institutional reforms proved pivotal in motivating local governments to exceed environmental targets, leading to tangible improvements in environmental quality. The *Assessment Method for Total Emission Reduction of Major Pollutants* further strengthened accountability, and the *Green Development Indicator System* prioritized ecological considerations over GDP growth in local evaluations. These changes have effectively reinforced the ETRS, signaling a profound shift toward integrating environmental sustainability into China's core governance framework.

The central government integrates environmental target responsibilities into officials' performance assessments, creating a competitive system. Performance rankings determine political rewards, providing strong positive incentives. However, unlike traditional competitive systems, this system incorporates a "one-ballot veto" and accountability mechanism: failure to meet binding targets diminishes an official's overall performance evaluation. This "knockout race" exerts a negative incentive, potentially leading officials to prioritize avoiding mistakes over pursuing ambitious goals (Chen & Gu, 2022), impeding progress toward ecological civilization. By increasing the weight of ecological civilization within this competitive performance evaluation system, the central government encourages performance competition. With limited resources, officials can improve their rankings by enhancing efficiency. This combination of competitive and knockout races compels officials not only to meet environmental targets to avoid penalties but also to compete with peers while balancing efficiency. In 2022, President Xi Jinping emphasized during the 36^{th} collective study session of the Politburo of the Central Committee the need for aligned Party and government responsibilities, clearly defined duties, and the integration of carbon peak and neutrality ("dual carbon") goals into regional economic and social development evaluations. He further stressed increasing the weight and strengthening the constraints of these indicators.

The structure of the remainder of this paper is as follows: Section 2 provides a review of the relevant literature; Section 3 presents the baseline model; Section 4 describes the model solution and numerical analysis; Section 5 offers an extension analysis; and Section 6 concludes with a summary of key findings and their associated policy implications.

2. Literature Review

The impact of environmental policy on environmental quality and economic growth is a significant topic in environmental economics, public economics, and economic growth theory. The relevant literature for this paper mainly includes:

2.1 Environmental Policy and Economic Growth

The Environmental Kuznets Curve (EKC) is used to study the impact of economic growth on environmental quality. According to the EKC, as per capita income rises from low levels, pollution emissions tend to increase, resulting in a decline in environmental quality. However, once per capita income exceeds a certain threshold, further increases in income lead to decreased pollution emissions and improved environmental quality. Existing literature, however, has increasingly focused on the reverse relationship—the impact of environmental quality on economic growth. Studies suggest that the negative impacts of declining environmental quality on economic growth can create an "environmental poverty trap", a situation where environmental degradation and economic stagnation reinforce each other (Mariani et al., 2010). The EKC reflects a "pollute first, clean up later" development approach, while the "environmental poverty trap" theory argues that the EKC relationship is not inevitable. Environmental policy can help economies escape this trap, but it must balance environmental protection with economic growth. This is not only a matter of efficiency but also of equity, as wealthier individuals may prioritize green amenities while lower-income individuals focus on income gains. Existing literature examines the economic effects of environmental policy from perspectives such as the "double dividend" hypothesis (Goulder, 1995; Lu, 2011), the "Porter hypothesis" (Porter & Linde, 1995; Liu & Xiao, 2022), and the "pollution haven" hypothesis (Copeland & Taylor, 2004; Jin & Shen, 2018). These studies provide important policy implications for balancing environmental protection and economic growth.

Environmental policy has direct and indirect effects on economic growth. Direct effects stem from how environmental policies influence households' consumption-saving decisions, labor-leisure trade-offs, and firms' investment strategies, which in turn affect resource allocation and overall economic growth. For example, within a dynamic general equilibrium framework, Bovenberg & Mooij (1997) and Chen et al. (2009) examined the economic growth impacts of environmental taxation, arguing that such taxes can reduce reliance on distortionary fiscal taxes, such as those on capital and labor income. This, in turn, can lead to higher equilibrium capital stock and income levels by encouraging labor supply and increasing savings. Indirect effects arise from how environmental policies influence household behavior and labor productivity through health improvements linked to environmental quality. For instance, Constant (2019) contends that environmental policies enhance environmental quality, leading to increased life expectancy. This, in turn, boosts returns to education, incentivizing greater household investment in education and thus driving economic growth. Chen & He (2017) found that energy tax policies improve worker health by improving environmental quality, with healthier human capital contributing to economic growth. Niu & Yan (2021) explored both the direct and indirect effects of environmental taxation on TFP, revealing that moderate environmental taxes can "reduce pollution, promote growth, and enhance welfare" by improving resource allocation and environmental health. However, the compliance costs associated with environmental policies can constrain economic activity. To mitigate the potential adverse effects of increased environmental costs on economic growth and social welfare, complementary policies should be implemented alongside environmental measures (Liu & Lyu, 2009).

2.2 Central Environmental Performance Evaluation and Local Environmental Governance

For a considerable period, local governments' strategic implementation of environmental policy has been a significant reason for the ineffective control of pollution. As economic development was above all else, performance evaluations became heavily focused on GDP growth. This created an incentive for local officials to boost economic output by increasing investments in high-pollution industries, often sacrificing environmental health in the process, in hopes of securing political promotion. In the new era, the central government introduced the "Five-Sphere Integrated Plan"[1], which incorporated construction of ecological civilization into the performance evaluation system. This shift in the central government's incentive structure for local governments influenced their behavior, ultimately impacting economic growth. Existing research primarily relies on empirical analysis to assess the effect of central environmental performance evaluations on local environmental governance and quality. Sun et al. (2014), using data from 86 major cities in China, found that the central government's environmental performance evaluations of local officials positively impacted their chances of promotion, and that changes to the evaluation mechanism were beneficial for sustaining the urban economy's growth. Zhang et al. (2020) concluded that since 2013, the reduction in GDP growth targets within evaluations, coupled with a greater emphasis on environmental protection, has led to a notable decline in the extent to which local governments promote economic growth through investment. Yu et al. (2020) found that linking local environmental target responsibility assessments to official promotions prompted local governments to encourage industrial upgrading and transformation by adjusting fiscal expenditure structures, fostering technological research and development, and undertaking technological renovations,

[1] "Five-Sphere Integrated Plan" refers to the development of socialism with Chinese characteristics encompassing economic, political, cultural, social and ecological development.

all of which contributed to high-quality economic development. Based on data from 277 Chinese cities, Hu & Zong (2022) demonstrated that mayoral promotions were more likely in cities that achieved rapid improvements in air quality, suggesting a competitive evaluation system for local officials. This performance-based system, which links environmental outcomes to career advancement, therefore, became a crucial mechanism for enhancing environmental quality in China.

The central government actively promotes local governments' efforts to improve environmental quality by implementing mechanisms such as environmental inspections, the "one-ballot veto" system for environmental performance, regulatory talks, and the ETRS. Research indicates that these institutional frameworks play a crucial role in shaping local government behavior, effectively driving positive changes in environmental outcomes. For example, Shi et al. (2017), analyzing data from 25 cities subject to public accountability discussions, found that holding local officials accountable for air pollution significantly boosted pollution control efforts. Similarly, Zhou et al. (2021) demonstrated that central environmental inspections had a deterrent effect on the cities, resulting in a reduction in PM2.5 levels during the inspections, although these levels typically spiked once the inspection teams left. Sun et al. (2022) further confirmed that these inspections improved air quality by prompting local governments to increase investments in environmental governance. However, they also identified a pattern where the cities would temporarily cut production during inspections, only to see output and pollution levels surge again afterward, pointing to potential collusion between local governments and businesses to evade lasting environmental improvements. Additionally, the ETRS has been shown to impact innovation outcomes. Tao et al. (2021) found that while the system positively influenced the number of green patent applications, it had a negative effect on the quality of green innovations. Similarly, Xie & Wang (2022), employing a difference-in-differences (DID) model, observed that the system led to a more significant reduction in economic growth targets in regions that achieved substantial emission reductions.

2.3 Brief Commentary

China's distinctive environmental governance policies play a pivotal role in advancing its ecological civilization. While empirical studies on the economic implications of the ETRS are relatively abundant (Yu et al., 2020; Tao et al., 2021; Xie & Wang, 2022), there is a notable gap in the literature regarding the use of dynamic general equilibrium (DGE) models to analyze this system. To date, the only significant theoretical work in this area is Zhang et al. (2020), who employed a neoclassical growth model to explore the effects of shifting local government performance evaluations from GDP growth targets to environmental protection goals. While other studies (e.g., Tong et al., 2016; Fan & Zhang, 2018) have developed theoretical frameworks to examine the economic impacts of environmental regulations, these primarily focus on the constraints imposed on polluting firms. In contrast, this paper approaches the ETRS as a mechanism through which central government policies influence local government behavior, with subsequent effects on firms' and households' optimal decisions. This perspective represents a significant departure from the existing literature on environmental regulation's economic effects.

In practice, the ETRS motivates local officials to achieve environmental goals set by higher levels of government by reinforcing environmental regulations and increasing investment in environmental protection. This emphasis on environmental responsibilities reflects the central government's strong commitment to enhancing environmental quality. This paper uses an economic growth model to explore the wider implications of the ETRS, examining its effects on environmental quality, technological innovation, economic growth, and social welfare. The system's effectiveness hinges on the adjustments made to the central government's incentive and constraint mechanisms for local governments. By modifying these mechanisms, the central government alters local governments' utility functions, which in turn influences the allocation of public resources at the local level, with far-reaching consequences for economic, environmental, and social outcomes. This paper integrates environmental quality and the ETRS into the classic economic growth model of Rivera-Batiz & Romer (1991), endogenizing the decision-making processes of both central and local governments. The potential contributions and innovations of this paper can be summarized in the following key aspects:

First, this paper introduces a novel modeling approach to China's unique ETRS by embedding it within a lab-equipment endogenous growth model. It analyzes the transmission mechanisms through which this system influences economic growth and social welfare, thus contributing to the broader literature on economic growth theory. The ETRS is incorporated into the model in three key ways: (1) Integration into the Production Function: The ETRS is reflected in the final goods production function, akin to an institutional arrangement or a direct influence on TFP. (2) Dynamic Environmental Quality Accumulation: The system is embedded within the dynamic equation for environmental quality accumulation. From an environmental governance efficiency perspective, a higher environmental target responsibility implies greater efficiency in local government environmental spending. This enhanced efficiency is a critical channel through which the system influences both environmental quality and economic growth. (3) Incorporation into Local Government Utility: The ETRS is included in local governments' utility functions, modeled using a Stone-Geary-type utility function. Here, the central government's environmental targets are treated as a subsistence constraint on local governments' environmental quality. These three specifications enable the ETRS to affect household, firm, and local government behavior through both direct and indirect channels, influencing key variables such as environmental quality and economic growth.

Second, this paper deepens our understanding of local government optimization behavior, emphasizing the impact of the ETRS on government actions. Empirical literature suggests that local governments often need to balance different objectives and are willing to tolerate slower GDP growth in order to achieve stricter environmental targets (Chen et al., 2018). This paper formalizes these empirical findings through a theoretical model. To highlight the importance of environmental target assessments, we incorporate environmental quality into local governments' utility function, where their efforts in environmental governance determine environmental outcomes. In the baseline model, we examine the trade-off local governments face between consumption expenditure and environmental governance expenditure. In the extended model, we introduce local government spending on science and technology into the R&D sector's production function. This allows us to analyze not only the trade-off between consumption and productive expenditures but also the internal trade-off within productive expenditures—specifically, between environmental governance and R&D spending. In this setup, the ETRS has a dual effect: it boosts economic output through increased productive expenditure but simultaneously crowds out R&D investment as more resources are directed towards environmental governance, thereby constraining long-term economic growth. This paper aims to emphasize the distorting effect of the ETRS on the structure of local government fiscal expenditure.

Third, this paper argues that a moderate increase in the ETRS can enhance environmental quality and accelerate technological innovation, fostering both green development and innovation-driven growth. However, excessively stringent environmental targets, while potentially improving environmental quality, could negatively affect technological innovation, suggesting a trade-off between the system's impact on green development and innovation-driven growth. Both green development and innovation-driven growth are critical components of high-quality economic growth, making their relationship with the ETRS a central focus of this study. This paper's model diverges from traditional economic growth frameworks—such as neoclassical, physical capital-driven, or human capital-driven models—by emphasizing technological innovation and environmental quality as the primary drivers of economic growth. With different growth drivers, the mechanisms through which environmental policy impacts economic growth and its effects can vary significantly.

Fourth, conclusions drawn from the quantitative analysis significantly expand on existing literature regarding the impact of environmental policy on economic growth and social welfare, offering fresh insights into the ETRS. Two key findings emerge from our quantitative analysis: (1) The ETRS set to maximize social welfare ($\overline{E}^{WEL}$) is stricter than the one set to maximize the economic growth rate ($\overline{E}^{GDP}$). This is reflected in the fact that the former's value is greater than the latter's, with the ratio of $\overline{E}^{WEL}/\overline{E}^{GDP}$ greater than 1. This suggests that while the ETRS can indeed improve social welfare, prioritizing it over economic growth may require trade-offs. To optimize social welfare, the implementation of stricter environmental targets is recommended. (2) Impact of Broader Well-Being Metrics on Economic Growth: The paper also explores the potential shift in local government evaluations, proposing that a broader measure of well-being—one that includes economic growth, environmental quality, and leisure—rather than solely focusing on GDP growth, could reshape outcomes. The findings indicate that the economic growth rate would experience only a modest decline when transitioning from a growth-maximizing objective to a social welfare-maximizing objective.

The divergent effects of environmental policies on economic growth versus social welfare is a critical area of study. While previous research has analyzed the impact of environmental taxes and government expenditures on environmental governance (Fullerton & Kim, 2008; Chen et al., 2009; Pautrel, 2012; Chu et al., 2018), there is, to our knowledge, a notable gap in literature regarding the specific effects of the ETRS on both economic growth and social welfare. This paper makes an important contribution to filling that gap, advancing our understanding of this complex and crucial issue.

3. Baseline Model

The inclusion of environmental indicators in local government performance evaluations has made environmental performance a key priority for local governments. Previous studies have shown that the ETRS significantly influences local government behavior (Yu et al., 2020; Zhang et al., 2020; Tu et al., 2021; Xie & Wang, 2022), with improvements in environmental quality notably increasing the likelihood of promotion for local officials (Sun et al., 2014; Hu & Zong, 2022). Building on this empirical evidence, this paper develops a model of China's distinctive ETRS. By integrating both the central and local governments into an endogenous growth framework, we endogenize environmental quality and examine the effects of the ETRS on local government behavior, environmental quality, economic growth, and social welfare. We also explore the transmission mechanisms underlying these effects.

3.1 Final Goods Sector[2]

The final goods sector is perfectly competitive. This sector uses labor and intermediate goods to produce final goods, with the following production function:

$$Y_t = \psi\left(E_t, \overline{E}\right) L_t^{\alpha} \int_0^{A_t} x_{it}^{1-\alpha} di \tag{1}$$

In Equation (1), Y_t represents the quantity of final goods produced in period t, L_t denotes the quantity of labor, x_{it} is the quantity of the i^{th} intermediate good, and A_t indicates the number of intermediate good varieties. Additionally, E_t represents environmental quality, while $\overline{E}$ refers to the ETRS. $\psi\left(E_t, \overline{E}\right)$ captures the combined effect of environmental quality and the ETRS on total output, and can also be interpreted as TFP.

Drawing from the literature, such as Fullerton & Kim (2008) and Chiroleu-Assouline & Fodha (2014), we introduce environmental quality into the production function. Specifically, we assume that improved environmental quality leads to an increase in output through channels such as better worker health. More formally, we assume that $\partial\psi\left(E_t, \overline{E}\right)/\partial E_t > 0$, meaning that higher environmental quality leads to an increase in TFP, thereby boosting the output of final goods.

The inclusion of the ETRS in the final goods production function mirrors the treatment of the system

[2] Due to space constraints, the solution process of the baseline model is available from the authors.

as an institutional arrangement or as a factor that directly affects TFP. This perspective is informed by the institutional economics approach, drawing on studies by Fabien (2013) and Li et al. (2020). Based on the empirical conclusions of Chen et al. (2018), He et al. (2020), and Xie & Wang (2022), it is assumed that $\partial\psi\left(E_t,\overline{E}\right)/\partial\overline{E}<0$, i.e., the ETRS will lead to a decrease in TFP[3]. This negative relationship arises because stricter environmental regulations imposed by local governments, as part of the ETRS, lead to increased oversight and tighter constraints on firms.

Existing studies highlight the detrimental effects of the ETRS on TFP. In response to environmental assessments, local governments may take actions such as "closing down, merging, and relocating" firms, which ultimately reduces overall output. The ETRS directly affects polluting firms and, considering upstream and downstream linkages between firms, also indirectly affects non-polluting firms (Xie & Wang, 2022). Environmental regulations can cause firms to shift resources from efficiency-enhancing production activities to pollution abatement, which can reduce firm productivity (Chen et al., 2018). The aforementioned literature provides empirical support for the model specification in this paper. We assume that local governments levy a tax on the final goods sector at a rate τ. The final goods sector maximizes profit by choosing the optimal quantities of labor and intermediate goods $\max\left[(1-\tau)\psi\left(E_t,\overline{E}\right)L_t^{\alpha}\int_0^{A_t}x_{it}^{1-\alpha}di-w_tL_t-\int_0^{A_t}p_{it}x_{it}di\right]$, where w_t is the wage rate and p_{it} is the price of the i^{th} intermediate good.

3.2 Intermediate Goods Sector

The intermediate goods sector must first purchase knowledge from the R&D sector as a production blueprint. This can be viewed as a one-time fixed investment. Based on the production blueprint design, the intermediate goods sector rents capital to produce intermediate goods, converting one unit of capital k_{it} into one unit of intermediate goods x_{it}, i.e., $x_{it}=k_{it}$. The intermediate goods sector is monopolistically competitive, and the product produced by each intermediate goods firm can be viewed as a blueprint-specific machine. The profit maximization problem for the intermediate goods sector is: $\pi_{it}=\max\left(p_{it}k_{it}-rk_{it}\right)$, where π_{it} represents the profit that the intermediate goods firm can obtain, and r represents the interest rate. Considering symmetry, the quantity of capital rented by each intermediate goods firm is equal, $x_{it}=k_{it}=K_t/A_t$, where K_t represents the total capital. Substituting this condition into the final goods sector's production function (Equation 1) yields the aggregate output function:

$$Y_t=\psi\left(E_t,\overline{E}\right)\left(A_tL_t\right)^{\alpha}K_t^{1-\alpha} \tag{2}$$

3.3 R&D Sector

Following Rivera-Batiz & Romer (1991), the dynamic knowledge accumulation equation for the R&D sector is:

$$\dot{A}_t=\delta R_t \tag{3}$$

In Equation (3), $\dot{A}_t$ represents the newly produced knowledge (a dot above a variable denotes its derivative with respect to time; for example, $\dot{A}_t$ represents dA_t/dt). $\delta>0$ is a parameter representing the R&D sector's production efficiency, and R_t represents R&D investment in the innovation sector. Here, A_t represents the stock of knowledge, which is also the number of varieties of intermediate goods. Our model is a variety-expanding, innovation-driven economic growth model, the core of which is that the new knowledge produced by the R&D sector promotes the expansion of the variety of intermediate

[3] This paper introduces the ETRS into TFP. An alternative approach would be to have the ETRS affect firms' costs, and thus their profit functions; these two approaches are essentially equivalent. Due to space constraints, the model specification that incorporates the ETRS through costs is available from the authors upon request.

goods, which is the engine of economic growth. The new knowledge produced by the R&D sector can be understood as patents or blueprints. The intermediate goods sector must first purchase new knowledge from the R&D sector as a design, and then use capital goods to produce intermediate goods, which are then crucial inputs for the production of final goods.

The price of a unit of knowledge produced by the R&D sector is P_{At}. The no-arbitrage condition for the R&D sector is: $P_{At}\dot{A}_t = R_t$. The left-hand side of the above equation represents the total revenue from newly produced knowledge in the R&D sector, and the right-hand side represents the costs that the R&D sector needs to pay. Following Romer (1990), the price of knowledge is equal to the discounted value of the profits of the intermediate goods sector: $P_{At} = \int_t^{+\infty} \pi_s e^{-\int_t^s r_\upsilon d\upsilon} ds$. Considering symmetry, the profits of each intermediate goods firm are equal, i.e., $\pi_{it} = \pi_t$. In this paper's model, when the economy converges to a balanced growth path, the growth rate of knowledge is equal to the growth rate of output, and also equal to the growth rate of R&D investment[4], thus the price of knowledge is constant. Taking the derivative of the knowledge price with respect to time t, we obtain $P_{At} = \pi_t / r$, which means that the price of knowledge is equal to the discounted monopoly profit of the intermediate goods sector.

3.4 Environmental Quality

Environmental quality depends on the environmental pollution generated by final goods production and local government investment or effort in environmental governance. Higher final goods production leads to higher pollution emissions, which deteriorates environmental quality. We use χ to denote the emission coefficient per unit of output, and total environmental pollution is given by χY_t. We assume that local government investment in environmental governance is G_{Et}, and that environmental governance depends not only on material investment but also on environmental governance efficiency. We assume that environmental governance efficiency depends on the environmental target responsibility $\zeta\left(\overline{E}\right)$, assuming $\zeta'\left(\overline{E}\right) > 0$. A stricter ETRS $\overline{E}$ leads to higher efficiency in the use of environmental governance expenditure. The real-world basis for this is that a stricter ETRS gives local governments a stronger incentive to improve environmental quality, which leads them to allocate environmental governance expenditure to projects that most effectively improve environmental quality and increase enforcement against polluting firms, all of which are conducive to improving the efficiency of environmental expenditure. Based on the above discussion, the effective investment of local governments in environmental governance can be expressed as $G_{Et}\zeta\left(\overline{E}\right)$. Following John & Pecchenino (1994) and Mariani et al. (2010), we assume the following dynamic equation for environmental quality:

$$\dot{E}_t = G_{Et}\zeta\left(\overline{E}\right) \big/ \left(\chi Y_t\right) - \eta E_t \tag{4}$$

In equation (4), η represents the environmental degradation coefficient. Although existing literature has incorporated government environmental governance expenditure into the dynamic equation for environmental quality, it typically assumes that there is only one level of government in the economy, and that environmental governance expenditure is a predetermined proportion of total fiscal expenditure (Xiao & Liao, 2014; Chen & He, 2017; Constant & Marion, 2019). The proportion of government environmental governance expenditure is exogenously given, and the strategic interaction between different levels of government is not considered. In our model, the central government determines the ETRS, and local governments endogenously determine their environmental governance expenditure based on the central government's environmental target responsibility, which in turn determines environmental quality and the economic growth rate.

[4] Due to space constraints, the detailed proof is available from the authors upon request.

3.5 Households

We assume that the representative household's welfare is based on consumption, leisure, and environmental quality. The representative individual has one unit of time endowment, which is allocated between labor, denoted by L_t, and leisure, denoted by $1-L_t$. The representative household's optimization problem is:

$$\max \int_0^{+\infty} \left\{ \ln C_t + \beta \ln\left(1-L_t\right) + \varphi \ln E_t \right\} e^{-\rho t} dt \tag{5}$$

In Equation (5), β>0 represents the individual's preference for leisure, φ>0 represents the household's preference for environmental quality, and ρ>0 is the time preference rate.

The household faces the following budget constraint equation:

$$\dot{K}_t = r_t K_t + w_t L_t + A_t \pi_t - C_t - R_t \tag{6}$$

3.6 Local Governments

China implements a strict ETRS, requiring local environmental quality to meet minimum standards, with the central government assessing the effectiveness of local governments' environmental governance. The implementation of the ETRS incorporates environmental targets into local government performance evaluations, thus increasing the importance of environmental factors in local government objective functions (Xie & Wang, 2022). We assume that local government utility is defined based on their own consumption and the central government's assessment of their environmental quality performance. The local government's objective function is:

$$\max_{\theta} \int_0^{+\infty} \left[\ln G_{Ct} + \phi \ln\left(E_t - \overline{E}\right) \right] e^{-\rho t} dt \tag{7}$$

In Equation (7), G_{Ct} is local government consumption, $\overline{E}$ is the ETRS, which also represents the minimum environmental requirement set by the central government for local governments. $E_t - \overline{E}$ is the extent to which local environmental quality exceeds the minimum environmental quality required by the environmental target responsibility. A larger value indicates that the local government has exceeded its environmental targets by a greater margin and achieved better environmental performance, thereby increasing its chances of promotion. In our model, environmental quality is endogenously determined by local government environmental governance effort. Therefore, the ETRS can be viewed as an environmental quality constraint imposed by the central government on local governments, or as the environmental quality target that the central government requires local governments to achieve. A stricter ERTS $\overline{E}$ indicates higher environmental standards set by the central government and greater pressure on local governments in terms of environmental governance. ϕ>0 represents the local government's relative preference for environmental quality, or the importance it attaches to environmental performance evaluations. ρ>0 is the time preference rate. We assume a Stone-Geary-type utility function, treating the environmental target responsibility set by the central government as a subsistence constraint faced by local governments regarding environmental quality. This utility function specification requires that environmental quality on the balanced growth path must be higher than the environmental quality stipulated by the ETRS. This specification aims to highlight the "one-ballot veto" mechanism of environmental performance evaluations for local governments.

Local governments use tax revenue from the final goods sector for environmental governance and their own consumption. The local government's budget constraint equation is: $\tau Y_t = G_{Et} + G_{Ct}$, where G_{Et} is local government expenditure on environmental governance and G_{Ct} is local government consumption expenditure. We assume that the proportion of local government revenue used for environmental governance expenditure is $\theta \in (0,1)$, i.e., $G_{Et} = \theta \tau Y_t$. The proportion used for consumption expenditure is $1-\theta$, i.e., $G_{Ct} = (1-\theta)\tau Y_t$. Local governments determine the structure of fiscal expenditure between environmental governance expenditure and consumption expenditure to maximize the welfare function (Equation 7). It should be noted that in reality, local government fiscal expenditure has many categories, not just environmental governance expenditure and consumption expenditure. Here, θ more reflects the degree of effort of local governments in environmental governance.

3.7 The Central Government

The central government's objectives evolve at different stages of development. China's economy has entered a "new normal", transitioning from a phase of high-speed growth to one of high-quality development. During the high-speed growth phase, the government's primary focus was on the rate of economic growth. In the model presented in this paper, the central government selects the ETRS with the aim of maximizing economic growth, thereby identifying the system that best promotes the growth rate.

In the high-quality development phase, however, the government's priorities shift. It no longer concentrates solely on economic growth but also seeks to optimize the economic structure and address issues of unbalanced and inadequate development. The ultimate goal is to meet the growing demands of the people for a better life and to improve overall welfare. In the context of the model discussed in this paper, during the high-quality development phase, the central government chooses the ETRS that maximizes household welfare.

$$\max_{\overline{E}} \int_0^{+\infty} \left\{ \ln C_t + \beta \ln\left(1 - L_t\right) + \varphi \ln E_t \right\} e^{-\rho t} dt \tag{8}$$

We assume that the central government possesses perfect information and, based on the optimality conditions of the final goods sector, the intermediate goods sector, the R&D sector, the representative household, and local governments, the central government sets the environmental target responsibility to maximize either economic growth or social welfare.

3.8 Macroeconomic Equilibrium

A competitive equilibrium in this economy is defined as a set of prices $\left\{w_t, r_t, P_{At}, p_t\right\}$, a set of policies $\left\{\tau, \theta, \overline{E}\right\}$, and a set of endogenous variables $\left\{C_t, L_t, K_t, \pi_t, R_t\right\}$ such that:

First, households maximize their welfare by choosing consumption and leisure;

Second, the final goods sector maximizes its profit by choosing the quantities of labor and intermediate goods;

Third, the intermediate goods sector maximizes its profit by choosing the quantity of intermediate goods;

Fourth, the R&D sector maximizes its profit by choosing R&D investment;

Fifth, local government revenue equals expenditure, and the local government budget constraint is balanced;

Six, the labor market is in equilibrium, with household labor supply equal to firm labor demand;

Seventh, the capital market is in equilibrium, with the aggregate household capital supply equal to the intermediate goods production sector's demand for capital;

Eighth, the final goods market is in equilibrium.

Substituting the optimality conditions of the final goods sector, the intermediate goods sector, and the R&D sector into the household's budget constraint equation, and combining this with the local government's budget constraint equation, we can derive the equilibrium condition for the final goods market:

$$Y_t = C_t + \dot{K}_t + R_t + G_{Et} + G_{Ct} \tag{9}$$

According to Equation (9), final goods are used for consumption, physical capital accumulation, R&D expenditure, environmental governance expenditure, and government consumption.

4. Model Solution and Numerical Analysis[5]

4.1 Solving for the Balanced Growth Path

When the economy converges to a balanced growth path (Barro & Sala-I-Martin, 2004), the growth rates of endogenous variables are required to be constant. We assume that the economic growth rate on the balanced growth path is γ. Assuming that the individual's labor endowment is 1, labor on the balanced growth path is constant, $L_t = L^*$. Environmental quality is constant, $E_t = E^*$, and the proportion of local government environmental governance expenditure is also constant, $\theta_t = \theta^*$. Substituting environmental expenditure $G_{Et} = \theta\tau Y_t$ into the dynamic equation for environmental quality (Equation 4) and rearranging, we obtain: $\dot{E}_t = \theta\tau\zeta\left(\overline{E}\right)/\chi - \eta E_t$. On the balanced growth path, $\dot{E}_t = 0$ is satisfied, which allows us to obtain the environmental quality on the balanced growth path:

$$E^* = \theta\tau\zeta\left(\overline{E}\right)/(\eta\chi) \tag{10}$$

By solving the household's optimization problem, we can derive the labor supply:

$$L^* = \frac{\alpha(\rho+\gamma)}{\alpha(\rho+\gamma)+\beta(\rho+\alpha\gamma)} \tag{11}$$

Assuming $\psi\left(E,\overline{E}\right) = E^m\left(B-\overline{E}\right)^{1-m}$, $\zeta\left(\overline{E}\right) = \overline{E}^n$, we can derive the equation determining economic growth:

$$(\rho+\gamma)^{1-\alpha} = (1-\alpha)^{2-\alpha}(\alpha\delta)^{\alpha}(1-\tau)\left[\frac{\theta\tau\overline{E}^n}{\eta\chi}\right]^m\left(B-\overline{E}\right)^{1-m}\left[(\rho+\gamma)+\frac{\beta}{\alpha}(\rho+\alpha\gamma)\right]^{-\alpha} \tag{12}$$

According to Equation (12), using the implicit function theorem, we can find that the impact of the ETRS on economic growth is ambiguous. The ETRS that maximizes the economic growth rate is given by $\overline{E}^* = mnB/(1-m+mn)$. If $\overline{E} < \overline{E}^*$, then $d\gamma/d\overline{E} > 0$, and the ETRS has a promoting effect on the economic growth rate. If $\overline{E} > \overline{E}^*$, then $d\gamma/d\overline{E} < 0$, and the ETRS has a restraining effect on the economic growth rate. The transmission mechanism corresponding to the above conclusions is that the impact of the ETRS on economic growth is mainly realized through two channels: On the one hand, a stronger environmental responsibility system leads to higher environmental quality, which is conducive to increasing final output and thus increasing R&D investment, which will promote economic growth. On the other hand, a stronger environmental responsibility system leads to lower TFP, which in turn reduces final output and R&D investment, thereby inhibiting economic growth. In this paper's framework, the economic growth rate is equal to the rate of technological progress. According to Equation (10), given local government environmental governance expenditure, the ETRS has a positive impact on environmental quality. Based on this, we can draw the following conclusions: Without considering the impact of the ETRS on local government behavior, there is a trade-off between green development and innovation-driven development. If $\overline{E} < \overline{E}^*$, an increase in the ETRS leads to a simultaneous increase in environmental quality and the rate of innovation growth. If $\overline{E} > \overline{E}^*$, an increase in the ETRS leads to an increase in environmental quality, but a decrease in the rate of innovation growth.

We now proceed with the analysis within a framework where local government environmental governance expenditure is endogenously determined. We can derive the local government's welfare level as follows:

$$\widetilde{U} = \frac{1}{\rho}\left\{\ln(1-\theta)+\ln\tau+\ln\frac{(\rho+\gamma)}{(1-\alpha)^2(1-\tau)}+\phi\ln\left[\frac{\theta\tau\overline{E}^n}{\eta\chi}-\overline{E}\right]+\frac{\gamma}{\rho}\right\} \tag{13}$$

[5] Due to space constraints, the solution process for the balanced growth path is available from the authors upon request.

Local governments maximize their own welfare by choosing the structure of fiscal expenditure θ, which yields the following optimality condition:

$$\frac{d\widetilde{U}}{d\theta}=\frac{1}{\rho}\left\{-\frac{1}{1-\theta}+\left[\frac{1}{\rho+\gamma}+\frac{1}{\rho}\right]\frac{d\gamma}{d\theta}+\phi\left[\frac{\theta\tau\overline{E}^{n}}{\eta\chi}-\overline{E}\right]^{-1}\frac{\tau\overline{E}^{n}}{\eta\chi}\right\}=0 \tag{14}$$

According to Equation (12), we can derive the impact of local government fiscal expenditure structure on economic growth as follows:

$$\frac{d\gamma}{d\theta}=\frac{m/\theta}{(1-\alpha)/(\rho+\gamma)+\alpha^{2}(1+\beta)/\left[\alpha(\rho+\gamma)+\beta(\rho+\alpha\gamma)\right]} \tag{15}$$

Substituting Equation (15) into Equation (14), we can obtain the environmental governance expenditure that maximizes local government welfare θ, which is a function of the environmental target responsibility $\overline{E}$.

Furthermore, we can derive the household welfare level as follows:

$$U=\frac{1}{\rho}\left\{\ln\frac{\alpha}{\beta}+(1+\beta)\ln\left(1-L^{*}\right)-\ln L^{*}+\ln\frac{\rho+\gamma}{(1-\alpha)^{2}}+\varphi\ln\frac{\theta\tau\overline{E}^{n}}{\eta\chi}+\frac{\gamma}{\rho}\right\} \tag{16}$$

Substituting the optimal θ determined by Equation (14) into Equation (12), we can obtain the economic growth rate under the endogenous local government environmental expenditure scenario. Further substituting this economic growth rate and the labor supply determined by Equation (11) into Equation (16), we can thus express the household's welfare function as a function of the environmental target responsibility system (ERTS).

4.2 Parameter Calibration

We use numerical simulation to examine the impact of the ETRS on economic growth, local government environmental expenditure, environmental quality, and social welfare. Following Guo et al. (2021), we assume the output elasticity in the production function is $\alpha=0.5$. Based on Liu & Lyu (2009), we assume the time preference rate is $\rho=0.02$. According to the *China Labor Statistical Yearbook (2021)*, the average weekly working hours of urban employees in China in 2020 were 47 hours. Considering that there are 7 days a week and 24 hours a day, the working time is $L=47/7/24=0.2798$, and thus leisure is 1-L=0.7202. Substituting these parameters into Equation (11), we can deduce $\beta=2.0592$. The individual's preference for the environment φ should be significantly smaller than the individual's preference for consumption and leisure β. In this paper, we set φ to one-third of (0.6864) β, and conduct robustness checks with φ's values of 0.5-0.9. Following Pautrel (2012), the emission coefficient χ should be between 0 and 1.

Environmental pollution is a multifaceted issue, encompassing air, water, and soil pollution, with each pollutant exhibiting distinct indicators. Therefore, a practical approach is to aggregate these various pollutants into a single, unified indicator for more effective analysis. This involves determining the coefficients for various pollutants, an area where, to our knowledge, no prior research exists. Alternatively, χ reflects the environmental cost of GDP, or the social cost of pollution, specifically within the context of China. Estimates by Yang et al. (2013) suggest that the cost of environmental pollution accounts for 8%–10% of real GDP. Based on this, we set the baseline to $\chi=0.1$, and conduct robustness checks using $\chi=0.05$ and $\chi=0.2$. Additionally, Liu (2013) indicates that the contribution of environmental factors to China's economic growth is lower than that of factor inputs and technology. Therefore, we set another baseline to $m=0.05$ and perform robustness checks with $m=0.03$ and $m=0.1$. The environmental quality depreciation rate should lie between 0 and 1 (Zhang, 1999; Mariani et al., 2010).We set the baseline environmental quality depreciation rate to $\eta=0.5$, and conduct robustness checks with $\eta=0.1$, $\eta=0.3$, $\eta=0.7$, and $\eta=0.9$[6]. Without loss of generality, the R&D sector's research efficiency parameter δ can be set to 1.

In the model presented in this paper, as outlined in Equation (7), the local government's utility function incorporates utility derived both from its own consumption and from the central government's environmental quality assessment. There are three primary scenarios regarding the local government's preferences between these two factors: (1) Environmental Quality Priority: The local government places a higher priority on environmental quality assessment compared to its own consumption. This corresponds to the case where $\phi>1$. (2) Equal Emphasis: The local government places equal importance on its own consumption and the environmental quality assessment. This is represented by a case where $\phi=1$. (3) Consumption Priority: The local government gives more weight to its own consumption than to the environmental quality assessment, corresponding to the case where $0<\phi<1$. We set the baseline value $\phi=1$. To assess the robustness of the model, we conduct sensitivity checks using alternative values, specifically testing weights of $\phi=0.1$, $\phi=0.5$, $\phi=1.5$, and $\phi=2$, respectively, to explore the varying priorities between consumption and environmental quality[7].

In the empirical literature, the ETRS is typically treated as an exogenous shock, with quasi-natural experiments used to assess its effects and impacts. Notable studies include those by Yu et al. (2020), Tao et al. (2021), and Xie & Wang (2022). However, the approach used in empirical literature to characterize the ETRS does not align with the measurement of the system in this paper. This paper constructs an endogenous growth model to examine the system's behavior along the balanced growth path.

The central government began implementing the ETRS during the 11th Five-Year Plan period (2006-2010). We referred to the *Outline of the Eleventh Five-Year Plan for National Economic and Social Development of the People's Republic of China* ("*11th Five-Year Plan Outline*"), the *12th Five-Year Plan Outline*, and the *13th Five-Year Plan Outline* for data on the planned targets and actual achievements of environmental indicators. Using these documents, we compiled the planned targets and actual reductions in major pollutants for the 11th, 12th, and 13th Five-Year Plan periods. The planned and actual cumulative reductions in two pollutants during the 11th Five-Year Plan period are as follows: The target for sulfur dioxide (SO_2) emissions was a 10% reduction, while the actual reduction achieved was 14.29%. For chemical oxygen demand (COD), the planned target was also a 10% reduction, with the actual reduction reaching 12.45%.

During the 12th Five-Year Plan period (2011-2015), the planned and actual cumulative reductions for four pollutants were as follows: The target for COD was a cumulative reduction of 8%, while the actual reduction achieved was 12.9%; for SO_2, the planned reduction was 8%, but the actual reduction reached 18%; ammonia nitrogen had a planned reduction of 10%, and the actual reduction achieved was 13%; finally, for nitrogen oxides (NOx), the target was a 10% reduction, with the actual reduction reaching 18.6%.

During the 13th Five-Year Plan period (2016-2020), the emission reduction targets for four major pollutants were as follows: a cumulative reduction of 10% for COD, 15% for SO_2, 10% for ammonia nitrogen, and 15% for NOx. In terms of actual achievements, the National Development and Reform Commission (NDRC), in its *Summary and Assessment of the 13th Five-Year Plan Outline* (Section 8: The Staged Goals of the Battle Against Pollution Have Been Successfully Completed)[8], reported that significant progress had been made in air pollution prevention and control. Specifically, the cumulative reductions in emissions for major pollutants were 13.8% for COD, 15.0% for ammonia nitrogen, 25.5% for SO_2, and 19.7% for NOx.

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[6] Due to space constraints, the related results are available from the authors upon request.
[7] Due to space constraints, the related results are available from the authors upon request.
[8] For specific details, please see: https://www.ndrc.gov.cn/fggz/fzzlgh/gjfzgh/202112/t20211225_1309622.html.

It should be noted that the *11^{th} Five-Year Plan Outline* mentioned two pollutants, while the *12^{th} Five-Year Plan Outline* and the *13^{th} Five-Year Plan Outline* mentioned four pollutants.

In the *11^{th}, 12^{th}, and 13th Five-Year Plan Outlines*, the cumulative pollutant reduction targets are classified as binding targets. Unlike expected targets, binding targets further clarify and strengthen government responsibilities. These targets are work requirements mandated by the central government to local governments and relevant departments, addressing public services and matters involving public interests. The government must ensure their achievement through the rational allocation of public resources and the effective use of administrative power.

The ETRS aims to reduce major pollutants and improve environmental quality. The planned targets for cumulative reductions in major pollutants in the *11^{th}, 12^{th}, and 13^{th} Five-Year Plan Outlines* reflect this environmental target responsibility. The more ambitious the planned target for pollutant reduction, the greater the environmental target responsibility. Achieving the actual reduction of major pollutants is a key indicator of environmental quality. The faster the reduction of these pollutants, the quicker the improvement in environmental quality.

We calculate the environmental target responsibility based on the planned targets for cumulative reductions in major pollutants during the 11^{th}, 12^{th}, and 13^{th} Five-Year Plan periods, and we measure environmental quality based on the actual achievements of cumulative pollutant reductions, thus establishing the baseline $\overline{E}$ and E^{*}. The average planned target for cumulative reductions in major pollutants during these periods is 0.106, while the average of the actual achievements is 0.163. Since both the planned targets and the actual achievements represent cumulative data over five years, we can also calculate the average annual planned target $\overline{E}=0.022$ and the average annual actual achievement for major pollutant reduction $E^{*}=0.035$[9].

The *11^{th}, 12^{th}, and 13^{th} Five-Year Plan Outlines* establish major pollutant reduction targets as binding indicators, incorporating their completion into the performance evaluations of local officials. This approach aligns with the ETRS modeled in this paper.

To examine the effects of the ETRS, this study utilizes data from the 11^{th}, 12^{th}, and 13^{th} Five-Year Plan periods, a time when the system was gradually implemented and matured. According to data released by the National Bureau of Statistics (NBS), China's economic growth rate displayed a general downward trend from 2006 to 2020. From 2006 to 2011, China's average annual growth rate exceeded 10%; between 2012 and 2019, it averaged approximately 6.5%. In 2020, the economic growth rate slowed to just 2%, primarily due to the impact of the COVID-19 pandemic. Based on the economic growth performance over this period, we set a baseline growth rate γ of 7.5%.

In the model used in this paper, the tax variable τ refers to local taxes, specifically the proportion of local tax revenue relative to GDP. We define the narrow tax rate as the ratio of local tax revenue to GDP. To account for non-tax revenue collected by local governments in the broader economy, we also consider the general local budgetary revenue divided by GDP as a representation of the broader tax rate. According to China's economic data, these two tax rates typically fall within the range of 7% to 12%. As such, we set the baseline local government tax rate at 9%, while also conducting robustness checks with values of 7% and 12%.

Regarding the parameters of the impact of the environmental target responsibility on environmental quality and TFP, there are no empirical estimates based on real data from China. We calibrate these

[9] To illustrate how this data is obtained, let us consider the ETRS as an example. Suppose the initial pollution level is P_0. If the target is to reduce pollution by $\overline{E}$ each year, then the pollution level in the fifth year would be $P_0\left(1-\overline{E}\right)^5$. The reduction from the first year to the fifth year is $P_0\left[1-\left(1-\overline{E}\right)^5\right]\Big/P_0=0.106$, from which we can calculate $\overline{E}=0.022$. Using the same logic, we can obtain the annual average reduction rate for major pollutants.

two parameters through the steady-state values of two endogenous variables. The specific approach is as follows: Substituting the baseline value of environmental quality $E^* = 0.035$ into Equation (10), we can deduce the parameter of the impact of the environmental target responsibility on environmental quality $n = 0.9696$. Substituting the baseline value of the economic growth rate $\gamma = 0.075$ on the balanced growth path into Equation (12), we can deduce the parameter of the impact of the environmental target responsibility $B = 0.9436$ on TFP.

4.3 Analysis of Macroeconomic Policy

We first examine the impact of the ETRS on local government environmental governance efforts. According to the theoretical model's specification, the direction of the impact of the ETRS on local government environmental efforts is ambiguous. On the one hand, higher environmental targets imply more stringent environmental quality requirements for local governments, which may compel them to increase investment in environmental governance to meet the targets set by the central government. This can be understood as the environmental pressure effect of the ETRS.

On the other hand, if the impact of the ETRS on environmental quality is sufficiently large, meaning that $E^* - E$ may increase amid improvements in the ETRS, then, according to the law of diminishing marginal utility, local governments may prioritize consumption over environmental governance. Specifically, in the local government objective function (Equation 7), when environmental quality reaches a high level, local governments may derive greater marginal utility from consumption relative to environmental quality. In this case, they would increase expenditure on consumption while reducing expenditure on environmental governance. This can be understood as the consumption substitution effect of the ETRS.

As shown in Figure 1, an increase in the ETRS leads to greater local government effort in environmental governance, suggesting that the environmental pressure effect outweighs the consumption substitution effect. Existing literature has found that environmental performance evaluations have shifted local economic growth from crowding out environmental governance investment to supporting it (Tu et al., 2021), which aligns with the conclusions drawn from this paper's theoretical model.

Based on this, we investigate the impact of the ETRS on economic growth and social welfare. Figure 2 illustrates the results from our numerical simulations. As shown, the relationship between the ETRS and economic growth follows an inverted U-shape. Specifically, there is a threshold level of the ETRS that maximizes economic growth $\overline{E}^{GDP}$. When the system is below this threshold, the economic growth rate is positively correlated with it; however, once the system exceeds this threshold, the correlation turns negative.

The underlying transmission mechanism can be explained as follows: On the one hand, the ETRS directly constrains the production of final goods. This occurs because higher environmental responsibility levels typically lead to stricter local government policies, which in turn limit TFP. On the other hand, the ETRS also influences environmental quality by shaping local governments' efforts in environmental governance. Our simulations show that as the ETRS strengthens, local governments allocate a larger proportion of resources to environmental governance, improving both expenditure efficiency and environmental quality (see Figure 1). This enhancement in environmental quality positively impacts output, for instance, by improving labor health.

Considering the combined effects of these two factors, the overall impact of the ETRS on economic growth remains ambiguous.

Social welfare is largely driven by economic growth. Consequently, the impact of the ETRS on social welfare also follows an inverted U-shaped relationship (see Figure 2). There exists a threshold level of the ETRS that maximizes social welfare in the economy $\overline{E}^{WEL}$. Additionally, environmental quality plays a crucial role in shaping social welfare within this model. As shown in Figure 1, the ETRS contributes to improved environmental quality, aligning with the empirical findings of Chen et al. (2018) and others.

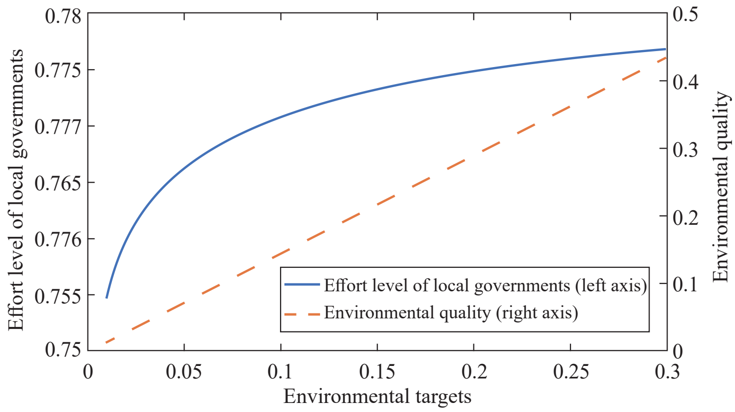

Figure 1: Impact of Environmental Target Responsibility on Local Effort and Environmental Quality

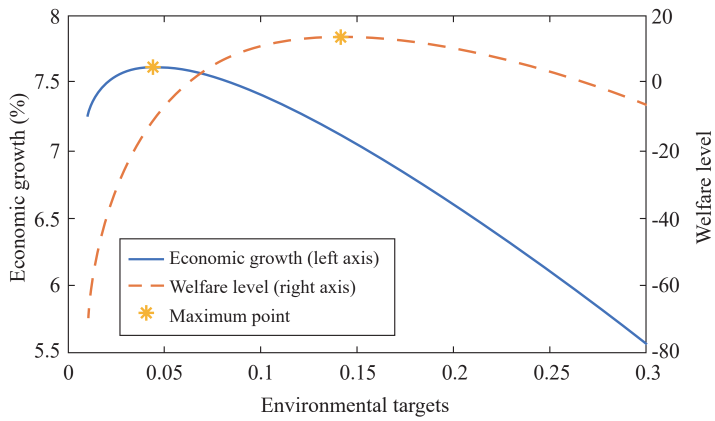

Figure 2: Impact of the ETRS on Economic Growth and Social Welfare

Compared to the ETRS that maximizes economic growth, the ETRS that maximizes social welfare lies further to the right on the scale, i.e., $\overline{E}^{WEL} > \overline{E}^{GDP}$. From a quantitative perspective, we examine whether the economic growth loss associated with shifting the central government's focus from maximizing economic growth to maximizing social welfare is substantial. According to Figure 2, the decrease in the economic growth rate is only -0.5161% when transitioning from the system that maximizes economic growth to the one that maximizes social welfare. This suggests that the economic cost of prioritizing social welfare over growth is relatively small, implying that such a policy shift does not result in significant economic growth losses.

Innovation-driven development and green development are two key pillars of China's high-quality economic growth. In the model presented in this paper, when the economy converges to a balanced growth path, the growth rate of technological innovation aligns with the economic growth rate, i.e., $\dot{A}_t / A_t = \dot{Y}_t / Y_t$. Thus, the impact of the ETRS on technological innovation is reflected by the economic growth rate curve in Figure 2.

As shown in Figure 1, the ETRS has a positive effect on environmental quality. Based on this, if $\overline{E} < \overline{E}^{GDP}$, it promotes both innovation-driven and green development. However, if $\overline{E} > \overline{E}^{GDP}$, while it benefits green development, it could hinder innovation-driven growth. Therefore, from the perspective of high-quality economic development, the ETRS should not be maximized or minimized indiscriminately. The optimal level of the ETRS depends on the relative importance assigned to innovation-driven development versus green development.

4.4 Robustness Checks

Given that the baseline values of model parameters and policy variables may influence the numerical analysis outcomes, we assume that these values vary within a reasonable range to minimize their potential impact on the results. We then examine the effect of the ETRS on economic growth and social welfare. As parameter adjustments involve numerous repeated simulations, presenting each result in a separate figure would require excessive space. To improve readability, the robustness check results are summarized in Table 1.

In Table 1, we pay particular attention to the sensitivity of three aspects of the conclusions. First, do the conclusions emphasized by this paper's theoretical model still hold? This can be judged by the shape of the economic growth rate curve, the social welfare curve, and the environmental quality curve, as shown in columns 3 and 4 of Table 1. As can be seen, the relationships between the economic growth rate curve, the social welfare curve, and the ETRS remain inverted U-shaped, and the environmental quality curve is monotonically increasing. This indicates that the main conclusions of this paper are robust.

Second, compared with the ETRS that maximizes economic growth, are there significant changes in the economic growth loss caused by the ETRS when pursuing social welfare maximization? As shown in column 5 of Table 1, the decrease in economic growth rate caused by social welfare maximization generally fluctuates around 0.5%, with a maximum decrease of no more than 1.16%, compared to maximizing economic growth. This shows that achieving social welfare maximization through the ETRS does not lead to excessive economic growth decline, and this conclusion is also robust.

Third, the ETRS designed to maximize social welfare is more stringent than the one aimed at maximizing economic growth. This is evident in the ratio of the ETRS for social welfare maximization $\overline{E}^{WEL}$ to the one for economic growth maximization $\overline{E}^{GDP}$, i.e., $\overline{E}^{WEL}/\ \overline{E}^{GDP}$ is greater than 1 (see column 6 of Table 1). This indicates that while the ETRS can enhance social welfare, it does so at the cost of economic growth. Moreover, from the standpoint of improving social welfare, a stricter ETRS should be implemented. This conclusion aligns with the results observed under the baseline parameter specification.

Table 1: Robustness Checks of the Baseline Model

Variable	Value	Inverted U-shaped	Increasing Environmental Quality	Change in Economic Growth Rate (%)	Environmental Target Responsibility Ratio $\overline{E}^{WEL}/\ \overline{E}^{GDP}$
Model parameters					
α	0.4	√	√	-0.5251	3.0468
	0.6	√	√	-0.5047	3.0253
ρ	0.01	√	√	-0.2138	2.2687
	0.04	√	√	-1.1511	4.0584
χ	0.05	√	√	-0.6114	3.0881
	0.2	√	√	-0.4152	2.9417
m	0.03	√	√	-0.6485	4.5115
	0.15	√	√	-0.2211	1.5068
η	0.3	√	√	-0.5891	3.1116
	0.7	√	√	-0.4654	3.0370
φ	0.5	√	√	-0.3232	2.5152
	0.9	√	√	-0.7555	3.6623
ϕ	0.5	√	√	-0.4892	3.0133
	2	√	√	-0.5371	3.0763
Policy Variable					
τ	0.07	√	√	-0.4816	3.0370
	0.12	√	√	-0.5606	3.0916
Baseline Scenario		√	√	-0.5161	3.0563

5. Extended Analysis

The baseline model explores the trade-off between local government spending on environmental governance and its consumption expenditure. In reality, local governments also face trade-offs within their productive expenditures. Building on the baseline model, we incorporate local government expenditure on R&D as an endogenous variable. This extension introduces a new mechanism by which the ETRS influences economic growth, offering a deeper understanding of its impact beyond the original model.

5.1 Theoretical Model

The basic specifications remain consistent with those outlined in Part 3 of this paper. However, a key difference is that we now assume technological innovation is influenced not only by firm R&D investments but also by government spending on innovation, G_{At}. In reality, the government plays a crucial role in fostering innovation through avenues such as funding basic research and enhancing intellectual property protection. We model the technological innovation production function in the R&D sector as follows:

$$\dot{A}_t = \delta R_t^{v} G_{At}^{1-v} \tag{17}$$

We assume that a proportion of local government fiscal expenditure θ is allocated to productive expenditure, while another proportion $1-\theta$ is directed toward consumption expenditure, such that $G_{Et}+G_{At}=\theta\tau Y_t$, $G_{Ct}=(1-\theta)\tau Y_t$. Within productive expenditure, a certain proportion μ is dedicated to environmental governance, and another $1-\mu$ to technological innovation. Consequently, the share of environmental governance expenditure relative to total fiscal expenditure is given by $\theta\mu$, $G_{Et}=\mu\theta\tau Y_t$ while the share of technological innovation expenditure relative to total fiscal expenditure is $\theta(1-\mu)$, hence $G_{At}=(1-\mu)\theta\tau Y_t$.

The inclusion of local government R&D expenditure in Equation (17) highlights the distorting effect of the ETRS on the composition of productive fiscal expenditure. This framework allows us to examine not only the trade-off between consumption and productive expenditures but also the internal allocation of productive expenditure between environmental governance and R&D investment.

By solving the model[10], we can obtain the impacts of the two fiscal expenditure structure variables on the economic growth rate as follows:

$$\frac{d\gamma}{d\theta}=\frac{\left[m+\alpha(1-v)\right]/\theta}{\frac{\alpha(1-v)}{\gamma}+\frac{\alpha^2(1+\beta)}{\alpha(\rho+\gamma)+\beta(\rho+\alpha\gamma)}+\frac{1-\alpha(2-v)}{\rho+\gamma}} \tag{18}$$

$$\frac{d\gamma}{d\mu}=\frac{m/\mu-\alpha(1-v)/(1-\mu)}{\frac{\alpha(1-v)}{\gamma}+\frac{\alpha^2(1+\beta)}{\alpha(\rho+\gamma)+\beta(\rho+\alpha\gamma)}+\frac{1-\alpha(2-v)}{\rho+\gamma}} \tag{19}$$

According to Equation (18), $d\gamma/d\theta>0$, which indicates that an increase in the proportion of productive fiscal expenditure leads to an increase in the economic growth rate. The mechanism behind this result is straightforward: increasing the proportion of productive fiscal expenditure boosts output by either enhancing environmental quality or increasing government investment in R&D. According to Equation (19), the productive fiscal expenditure structure corresponding to the maximization of the economic growth rate is $\overline{\mu}=m/\left[m+\alpha(1-v)\right]$. If $\mu<\overline{\mu}$, then $d\gamma/d\mu>0$, which means that an increase in the proportion of environmental expenditure leads to an increase in the economic growth rate; if $\mu>\overline{\mu}$, then $d\gamma/d\mu>0$, which means that an increase in the proportion of environmental expenditure leads to a decrease in the economic growth rate.

[10] Due to space constraints, the detailed solution of the extended model is available from the authors upon request.

The mechanisms involved are as follows: On one hand, local government environmental expenditure stimulates economic growth by improving environmental quality. On the other hand, it can hinder economic growth by crowding out research and development (R&D) spending. Consequently, from the perspective of maximizing economic growth, there is an optimal balance between local government environmental expenditure and R&D expenditure. By solving the local government's optimization problem, we can determine this ideal expenditure structure. The extended model, unlike the baseline model, incorporates the ETRS, which influences economic growth through two channels: (1) by affecting the allocation between productive and consumption expenditures; and (2) by shaping the balance between environmental governance and technological innovation spending within productive fiscal expenditure.

5.2 Numerical Analysis

We use numerical simulation to study the impact of the ETRS on economic growth, the structure of local government fiscal expenditure, and social welfare. The basic parameter values are the same as in the baseline model. For the newly added parameter v, based on data released by the National Bureau of Statistics (NBS), we calculated the proportion of firm expenditure in China's internal R&D expenditure from 2006 to 2020. The proportion of firm expenditure in China's R&D expenditure increased from 69.05% in 2006 to 77.46% in 2020, with an average of 74.01%. Therefore, we set $v=0.75$. Considering the differences in the proportion of firm expenditure across different years and regions, we conduct robustness checks with $v=0.7$ and $v=0.8$. Substituting the baseline values of environmental quality and the economic growth rate into the relevant equations, we can deduce $n=0.9269$ and $B=1.2784$.

Unlike the baseline model, this extended model not only considers the structure of productive and consumption-related fiscal expenditures but also incorporates the interaction between environmental spending and technological innovation spending within the productive fiscal expenditure framework. As shown in the left panel of Figure 3, the ETRS results in an increase in the share of productive fiscal expenditure, with a notable rise in the proportion allocated to environmental governance within that category. The right panel of Figure 3 further illustrates that the ETRS leads to a higher proportion of local government environmental expenditure, but simultaneously reduces the share dedicated to technological innovation spending. It is important to highlight that in the extended model, local government technological expenditure plays a crucial role in driving innovation and economic growth. Therefore, caution is needed regarding the potential crowding-out effect of the ETRS, which could lead to excessive local government spending on environmental governance at the cost of technological innovation investment.

According to Figure 4, the impact curves of the ETRS on both economic growth and social welfare follow inverted U-shaped relationships. Notably, the ETRS that corresponds to the peak of the social welfare curve is positioned further to the right compared to the one associated with the peak of the economic growth curve. This observation aligns with the findings of the baseline model.

Moreover, when transitioning from the ETRS that maximizes economic growth to the one that maximizes social welfare, the economic growth rate changes by only -0.4615%. This minimal decrease indicates that shifting the system's focus from economic growth to social welfare does not result in a significant loss of economic growth, which is also consistent with the baseline model's conclusions.

In the extended model, the technological innovation growth rate remains equal to the economic growth rate. As a result, the impact of the ETRS on technological innovation also follows an inverted U-shape. The left panel of Figure 3 further reveals that the ETRS leads to improvements in environmental quality, suggesting that it plays a positive role in promoting green development.

In summary, the analysis reveals a trade-off between innovation-driven development and green development under the ETRS. While a higher ETRS supports green development, it may come at the cost of hindering innovation-driven growth.

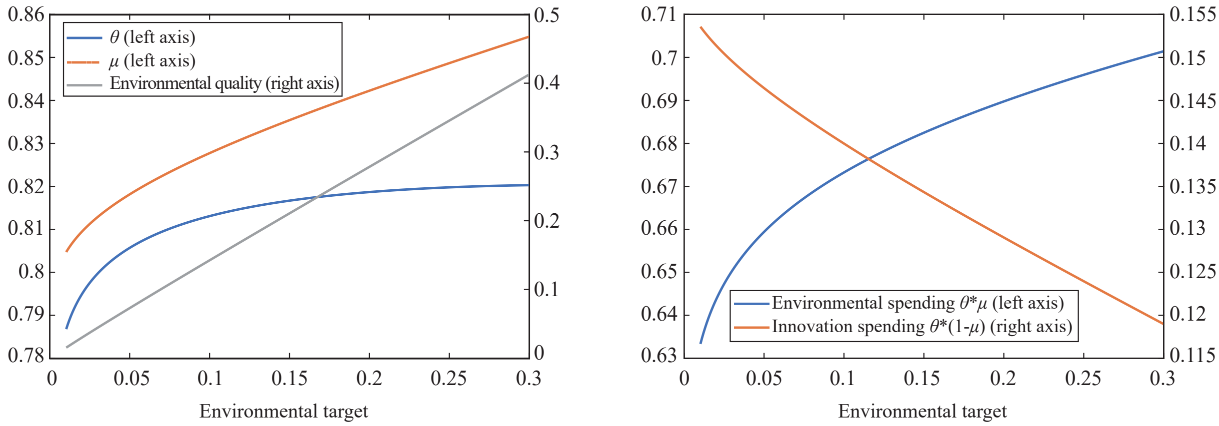

Figure 3: ETRS's Impact on Local Fiscal Spending Structure and Environmental Quality

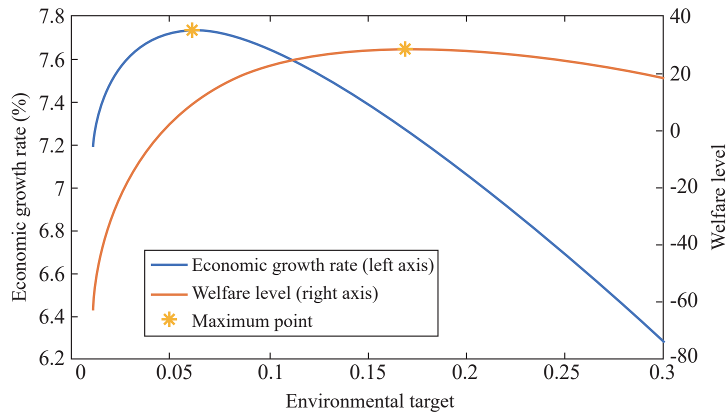

Figure 4: Effects of the ETRS on Economic Growth and Social Welfare

We assess the robustness of our conclusions by varying the model parameters and policy variables within a range that aligns with real-world plausibility. The specific results are presented in Table 2. As shown, the outcomes of the robustness checks align closely with those derived from the baseline parameter values. The relationship between the ETRS and both economic growth and social welfare follows an inverted U-shape, while environmental quality consistently improves in a monotonic fashion. This suggests a trade-off between fostering innovation-driven development and advancing green development within the framework of the ETRS. According to Table 2, the ETRS that maximizes economic growth is less stringent than the one that maximizes social welfare. However, the economic growth rate decreases by only about 0.5% on average when moving from the growth-maximizing to the welfare-maximizing configuration, with a maximum decline of no more than 1.06%. These findings are consistent with the baseline parameter results, further supporting the conclusion that the economic growth-reducing effect of the ETRS is marginal.

6. Concluding Remarks and Policy Implications

Since the reform and opening-up policy was adopted in 1978, China's development strategy has shifted from "focusing on economic development" to adopting the "Five-Sphere Integrated Plan", which emphasizes more comprehensive, balanced, and coordinated development. The central

Table 2: Robustness Test for the Extended Model

Variable	Value	Inverted U-shaped Curves	Increasing Environmental Quality	Change in Economic Growth Rate (%)	Environmental Target Responsibility Ratio $\overline{E}^{WEL}/\overline{E}^{GDP}$
Parameter					
α	0.4	√	√	-0.4804	2.8483
	0.6	√	√	-0.4411	2.6704
ρ	0.01	√	√	-0.1832	2.0902
	0.04	√	√	-1.0595	3.6115
χ	0.05	√	√	-0.5573	2.8328
	0.2	√	√	-0.3561	2.6304
m	0.03	√	√	-0.5870	4.0409
	0.15	√	√	-0.1858	1.4152
η	0.3	√	√	-0.5353	2.8278
	0.7	√	√	-0.4091	2.7010
φ	0.5	√	√	-0.2832	2.2908
	0.9	√	√	-0.6814	3.2876
ϕ	0.5	√	√	-0.4173	2.7061
	2	√	√	-0.4871	2.7722
v	0.7	√	√	-0.4495	2.6871
	0.8	√	√	-0.4724	2.8041
Policy Variable					
τ	0.07	√	√	-0.4192	2.7308
	0.12	√	√	-0.5015	2.7976
Baseline Scenario		√	√	-0.4615	2.7647

government has moved away from a performance evaluation system based exclusively on GDP and introduced a diversified evaluation framework that includes environmental performance. As a result, local governments are now tasked with balancing multiple objectives to optimize their overall utility. A substantial body of empirical literature suggests that while environmental performance evaluations have led to increased local government efforts in environmental governance, they have also resulted in a decline in economic growth (Chen et al., 2018; Zhang et al., 2020). In this context, the paper aims to model China's unique environmental governance system by constructing an endogenous growth model with an ETRS within a two-level framework involving central and local governments. The study explores how the ETRS influences the behavior of local governments, firms, and households, and how changes in these behaviors impact economic growth and social welfare. Furthermore, green development and innovation-driven growth are not only key drivers of economic growth but also fundamental elements of the new development philosophy. Given the positive externalities associated with both, government intervention through fiscal resources is necessary to correct market failures. This paper also examines how the ETRS affects the allocation of local government efforts between environmental governance and innovation.

Our research provides a theoretical explanation for the improvement in environmental quality in China under the ETRS. The policy implications of this paper can be summarized as follows:

First**,** effective performance evaluations are essential for local officials to fully embrace green development. Our findings suggest that a dual evaluation system, which incorporates both economic growth and environmental quality, has driven local government officials to focus more on environmental governance. This system has addressed the previous shortcomings in environmental protection implementation by local authorities. Given the ongoing challenges of unbalanced and insufficient development, strengthening the performance evaluation system and fostering a shift in local officials' development priorities are vital institutional steps toward achieving a harmonious relationship between man and nature. We recommend: 1. Improving the performance evaluation indicator system to better mobilize local governments' commitment to environmental protection. 2. Exploring a "three-in-one" performance evaluation mechanism, which includes vertical assessments by higher authorities, horizontal evaluations by peers, and feedback from the public. This approach would ensure the objectivity, fairness, and credibility of environmental quality assessments. 3. Establishing a performance evaluation system with both incentives and constraints, combining positive rewards such as promotions, commendations, and awards, with negative incentives such as accountability measures, to encourage local officials' proactive engagement in environmental governance.

Second, a scientifically designed ETRS is essential to achieve a dynamic balance between ecological protection and economic development. The research presented in this paper indicates that the existing system has led to improvements in environmental quality. Further enhancements to this system will help synergistically drive carbon reduction, pollution control, green expansion, and economic growth, thereby ensuring both high-level ecological protection and high-quality economic development. On the one hand, it is recommended to refine the ETRS by constructing a more comprehensive set of targets. This should include metrics for air, water, soil, emerging pollutants, total carbon emissions, and carbon intensity, along with a stronger focus on assessing the interplay between carbon reduction, pollution control, green expansion, and economic growth. Political and economic incentives for the system's implementation should also be strengthened, including central environmental inspections, interviews, and the allocation of special funds to support the system's effectiveness. On the other hand, our research suggests implementing a differentiated ETRS. Given the need to balance environmental quality with economic growth, it is crucial to set appropriate targets based on the specific circumstances of different regions. A practical approach would be to categorize national land into four key functional zones: optimized development zones, key development zones, restricted development zones, and prohibited development zones. The central government should tailor the ETRS to the unique needs of each zone, avoiding a one-size-fits-all strategy. For example, in prohibited development zones, the focus should shift to ecological restoration and governance, while economic growth targets should be phased out.

Third, integrate environmental policies and innovation policies to promote the coordinated development of green growth and innovation-driven development. Our research finds that while the ETRS has led to increased local government spending on environmental governance, it has also crowded out spending on innovation, creating a dilemma for local governments in balancing these two areas. The policy strategies proposed in this paper are: increase revenue, reduce expenditure, and improve efficiency. Increasing revenue: Given that the ratio of R&D and environmental governance spending to GDP is relatively low, it is necessary to further raise these expenditure ratios. Due to the fiscal pressures facing local governments, it is necessary to establish a market-oriented and diversified funding mechanism to broaden investment and financing channels for environmental protection and R&D innovation. Reducing expenditure: Both environmental protection and R&D innovation have positive externalities, and the government uses fiscal subsidies to address market failures. However, there may be instances of overlapping and cross-subsidies. It is necessary to coordinate subsidy policies across various departments to minimize duplication and reduce policy costs. Improving efficiency: Optimizing the structure of fiscal expenditure and improving its efficiency is crucial. The central government should increase the intensity of ecological transfer payments, particularly to key ecological function zones, central and western regions, and minority autonomous regions, to reduce local fiscal pressure and avoid the crowding-out effect on innovation investment. Additionally, it is important to establish and improve a stable fiscal subsidy system for green technology R&D and innovation investment. This includes enhancing tax incentives to support energy conservation, environmental protection, and green development, which would encourage enterprises to increase investment in green and low-carbon R&D and technological innovation, ultimately reducing government costs related to environmental governance through the advancement of green and low-carbon technologies.

Fourth, establish incentive policies that correspond with the ETRS to counteract its potential dampening effect on TFP through technological innovation and optimal resource allocation. Our findings suggest that an excessively stringent ETRS can limit both economic growth and social welfare. Possible solutions include: developing market-driven initiatives for green technology research, development, commercialization, and application. These initiatives can not only spur green innovation but also enhance the allocation of green technology resources, fostering the growth of new business formats, models, and industries, which in turn can generate new economic growth opportunities. It is essential to improve the financing environment for green technology innovation by expanding channels such as green credit, green bonds, and green funds. Another key step is strengthening the construction of a unified national market for emissions trading permits and carbon trading rights. This would incentivize enterprises to increase green R&D investments, improve resource utilization, and thus raise production efficiency. Simultaneously, market transactions between enterprises could enhance the efficiency of ecological resource allocation. Finally, adjusting the capital allocation structure, establishing environmental incentive policies, and guiding capital flows to green industries will promote the green transformation of the industrial structure and improve the efficiency of resource allocation.

A key limitation of this paper's model is that it does not account for environmental taxes. As China's environmental tax system is still in its early stages, both its total value and its proportion within the economy remain relatively modest. However, as environmental taxes gain prominence in China's evolving environmental governance framework, their influence will undoubtedly increase. While the current model provides valuable insights, the increasing importance of environmental taxes in China necessitates their inclusion in future dynamic general equilibrium analyses of the ETRS, economic growth, and social welfare.

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