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Can Environmental Tax Policy Really Help to Reduce Pollutant Emissions? An Empirical Study of a Panel ARDL Model Based on OECD Countries and China

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Received: 14 July 2019; Accepted: 8 August 2019; Published: 13 August 2019

Abstract: Under the background that environmental tax has increasingly become the main means of environmental governance in various countries, it is particularly important to study the effect of environmental tax on reducing pollutants and then put forward suggestions for building a scientific and rational environmental tax system. The novelty of this paper is the investigation of the pollutant emission reduction effects of environmental taxes in Organization for Economic Cooperation and Development (OECD) countries and Chinese provinces at the same time, and further comparison of the pollutant emission reduction effects of environmental taxes in OECD and China under different environmental tax collection scales, industrial added value levels, and economic development conditions based on Auto-Regressive Distributed Lag Modelling Approach (ARDL). The data are derived from environmental taxes and pollutants of OECD countries from 1994 to 2016 and Chinese provinces from 2004 to 2016. The results show that from the overall regression results, environmental taxes really help to reduce pollutant emissions, both in OECD countries and China. From the grouping regression results, the OECD countries and Chinese inland provinces with small-scale or medium-level of environmental tax revenue and higher level of economic growth all show better emission reduction effects, while OECD countries with low industrial added value and Chinese inland provinces with high industrial added value have more significant effects on pollutant emission reduction via environmental taxes.

Keywords: environmental tax; effectiveness of emission reduction; international comparison

1. Introduction

After World War II, the rapid development of the world economy produced many environmental problems [1–5]. CO_2 emissions in resource-related manufacturing showed an increasing trend due to the extensive production structure [6], which means it is of great importance not only to improve energy consumption efficiency further and promote sustainable energy transformation [7], but also to pay attention to the adjustment of the economic development model to avoid shifting to a higher energy consumption level [8]. Specific approaches may include a sustainability transformation, which would require changing far more than patterns of energy supply and use [9], and the improvement of the pace of transformation from secondary industries to tertiary industries [8]. Moreover, promoting the principles of a circular economy and the new business models advocated by the circular economy can represent a solution that is less dependent on primary energy resources and more environmentally friendly [10].

As we all know, achieving a sustainable economy depends on investing sufficient capital to finance the (possible) long-term transition of the real economy [11], so a finance ecosystem approach is required that ensures complementary forms of finance for low carbon investment [12]. Green finance is a phenomenon that combines the worlds of finance and business with environmentally friendly behavior [13], which will provide an opportunity to achieve environmentally sustainable innovation pathways, but it does not actually prevent the environmental protection industry from facing institutional and financial criticalities in funding their investment projects [14]. For example, the capital market frictions that arise from green investments increase the cost of external capital for enterprises that try to finance their investment projects [15], and the presence of a multiple credit relationship could concretely hinder a firm's investments in environmental innovations [11].

Under the premise of solving the problem of environmental protection funding sources, the use of funds should be further considered. Renewable energy source consumption plays a significant role in economic growth [16], which makes it meaningful to assess the importance of project finance for renewable energy projects in investment-grade countries, as well as underlying drivers [17]. However, some financial actors skew their investment to a subset of technologies (e.g., public utilities towards offshore wind), while others spread their investments more evenly over a wide portfolio of competing technologies [18], so we can promote the use of renewable energy to achieve environmental protection through active financial tools [13]. On the other hand, green product innovation mediates the relationship between green process innovation and a firm's financial performance [19], and such innovation can create value in terms of social sustainability [20]. In order to meet the Paris climate target, greater attention should be given to the role of innovative, low carbon, early stage businesses and the public sector's role in addressing financial gaps for longer horizon investment requirements [12].

Although the transformation of consumption patterns and green innovation investment are conducive to environmental protection and environmental sustainability to a large extent, this process is hindered by problems, such as long implementation periods and shortage of funds to some extent. The mandatory and fixed nature of environmental tax solve the problem of funding sources for environmental protection, and it is generally believed that an environmental tax can provide incentives for long-term effective development, transformation of consumption patterns, and green innovation investment. The OECD has already introduced an environmental tax and has experienced a long period of development and improvement, while China has gradually established an environment-related tax system by drawing on the experience of Western countries. The development of environmental taxes in both the OECD and China are shown in Table 1.

OECD countries and China highly praise environmental taxes, but do environmental taxes really help to reduce pollutant emissions? Patuelli et al. made a comparative study of a CGE model and a macroeconomic model and found that environmental taxes have a green dividend of carbon dioxide emission reduction [21]. Arbolino et al. found that environmental taxes in 26 European countries improved environmental quality on the whole [22]. Freire-González et al. proved that environmental tax reforms helped reduce pollutant emissions in 39 key industries in Spain [23]. Similarly, Rodríguez et al. found that green tax reform makes contributions to achieving improvements in the energy–trade balance and energy independence, as well as in reduction of the energy intensity of the Portuguese economy [24]. However, a coin has two sides; Bruvoll et al. [25] and Lin et al. [26] both did not agree that the "green dividend" of a carbon tax on per capita CO_2 emissions resulted in reduction in Norway. Nerudova et al. found that the Czech Republic's environmental tax has not yet reduced carbon dioxide emissions [27]. Carraro et al. studied whether the environmental taxes of 12 European Union countries play a role in energy saving and emission reduction in the short term, while the "green dividend" disappears in the long term [28]. Nerudová et al. argued that environmental taxes in the 15 European Union countries have aggravated environmental pollution [29]. Abdullah et al. also pointed out that environmental taxes in European Union and OECD countries do not have green dividends to reduce environmental pollution [30]. Similarly, He et al. concluded that an environmental tax does not have a significantly positive effect on reducing greenhouse gas emissions in the OECD [31]. Thus, it can be seen that scholars have extensively discussed the effects of environmental taxes on emission reduction, but there is no unified conclusion yet.

Table 1. The developments of environmental tax in Organization for Economic Cooperation and Development and China.

Object	Year or Time Period	Environmental Tax Development Stage
OECD Countries	In 1972	Put forward the "polluter pays" principle, which requires polluters to bear the cost of pollution and internalize the external cost.
OECD countries	In the 1980s	Adopted taxes on pollution, products, and energy to protect the environment and guide people's consumption behavior.
	After the 1990	Began to implement green tax reforms and use economic tools to change energy consumption behavior.
	In the mid-1990s	The environmental tax policy has evolved from a fragmented tax system, levied only for individual environmental taxes, to gradually form a sound environmental tax system.
	Early 21st century	In addition to imposing environmental taxes on a wider range of products or activities, the existing taxes will also be adjusted to achieve the goal of a comprehensive "green" tax system.
	At present	Environmental tax system has been generally established, which has become the main means of environmental policy in many countries.
China	In August 1973	Formulated "*Several Provisions on the Protection and Improvement of the Environment (Draft Trial Implementation)*"
	In 1979	*Environmental Protection Law of the People's Republic of China (for trial implementation)* was promulgated and implemented.
	In the 1980s	Implemented a tax reform and began to collect taxes related to environmental protection.
	In 2014	Put forward the content of tax system reform of "Promoting the reform of consumption tax and resource tax, doing a good job of legislation related to real estate tax and environmental protection tax".
	On 1 January 2018	Introduced the environmental tax, which has become the 18th tax category in China, providing more solid legal and economic guarantees for environmental protection and governance.

This paper collects data concerning 35 OECD countries for the period between 1994 and 2016, as well as 31 Chinese provinces for the period from 2004 to 2016, measuring the difference in pollutant emission reduction effects between OECD and China's environmental taxes under overall and different conditions based on the green dividends of environmental taxes. Some OECD countries levied environmental taxes earlier, and China is a developing country with large emissions of pollutants. This paper studies the effect of environmental taxes in the OECD and China on pollutant emission reduction, and provides suggestions to further improve the environmental tax system, ultimately achieving the goal of global emission reduction.

There are three major contributions of this paper. Firstly, this paper enriches the research methods of existing literature. The Auto-Regressive Distributed Lag Modelling Approach (ARDL) selected for the model overcomes the endogeneity problem, while breaking through the limitations of the same order and single integer; the lag period used in data processing is more consistent with the hysteresis effect of environmental tax emission reduction effect. Secondly, this paper expands the research perspective of an environmental tax green dividend. The existing literature mainly focuses on carbon taxes and carbon dioxide. This paper takes the OECD total environmental protection tax revenue and Chinese quasi-environmental tax revenue as the main research object, and extends pollutants to sulfur oxides, nitrogen oxides, industrial solid waste, and common indicators of wastewater pollution. Thirdly, this paper enriches the international comparative literature on the effect of environmental tax reduction. On the one hand, the existing literature on international comparison of environmental taxes mainly compares the differences in environmental taxation systems between different countries, and there is very little literature on quantitative analysis of environmental tax reduction effects and international differences. On the other hand, this paper further examines the heterogeneity of emission reduction effects of environmental taxes in OECD countries and provinces in China under different groups, providing relevant data support for the formulation of national and regional differential environmental taxes. Therefore, this study makes up for the existing literature.

The paper is organized as follows. Section 2 presents a literature review and puts forward the research hypothesis. Section 3 defines the variables and presents the research model. Section 4 presents the empirical results and analysis. In Section 5, the robustness test is presented. The last section is conclusions.

2. Literature Review and Hypothesis

2.1. Literature Review

In addition to some literature confirming the effect of an environmental tax on pollutant reduction [21–24], there is also some literature concerning the positive effects of environmental tax rates and specific environmental taxes on emission reduction. Rapanos et al. confirmed that an environmental tax in Greece would curb carbon dioxide emissions when the tax rate reached the highest level in the European Union [32]. Mardones et al. also pointed out that a high-tax-rate environmental tax would curb the carbon dioxide emissions of some Latin American countries [33]. Allan et al. proved that by imposing a tax of £50 per ton of CO2, this would meet the 37% CO_2 reduction target in Scotland [34]. Zhou et al. found that the appropriate carbon tax rates among different transport sectors and different energy categories are different in China [35]. The research on the emission reduction effect of specific taxes mainly focuses on carbon taxes and energy taxes. Siriwardena et al. proved that carbon taxes in Sri Lanka in the electricity sector cause a visible reduction [36]. Orlov et al. found in their study that carbon tax can reduce greenhouse gas emissions in Russia's macroeconomic sector [37]. Vera et al. agreed that carbon tax passed by the Chilean government will produce an expected annual reduction in CO2 emissions of 1% with respect to the estimated baseline during 2014–2024 [38]. The same conclusion made by Justin et al. also found that carbon tax effectively reduces carbon dioxide abatement costs and improves energy efficiency in the U.S. power sector [39]. Regarding an energy tax, Sancho acknowledged the elasticity of energy tax policies that would generate the highest reduction in carbon dioxide emissions is the substitution elasticity among energy goods [40]. Tang et al. also agreed that the total carbon emissions and other main air pollutants would be significantly mitigated in the coal resource tax reform of China, which can effectively improve the environment and guarantee the achievement of China's promise of carbon emissions reduction [41]. Similarly, Peng et al. concluded that the energy excise tax is beneficial for energy saving, and also confirmed that when the energy tax revenue is used to compensate for welfare losses, a double dividend effect of the energy excise tax will be achieved [42].

Regarding the partial affirmation or negative attitude toward the effect of an environmental tax on emission reduction, the main research objects are concentrated in a single country or in the European Union and OECD as a whole [25–31]. In questioning the effect of specific environmental taxes on emission reduction, Lee et al. found that Japanese carbon tax reform had only a small impact on emission levels by using a global macro-econometric model [43]. Fu et al. also proved that a vehicle registration tax (VRT) as well as motor taxation exhibited little impact on carbon emissions alone. Further research found that the greatest CO_2 reductions are achieved through a combined policy package of fuel tax and VRT and motor tax changes [44]. Yi et al. pointed out the fact that carbon tax policy does not always exert positive effects, as it depends on the initial level of pollution and the level of carbon tax [45].

Further literature review revealed that there are some comparative literature studies on the effect of environmental tax emission reduction. In terms of country comparisons, Radulescu et al. concluded that the environmental taxes of both Romania and the European Union have good performance in environmental protection [46]. He et al. explored the relationship between environmental tax, environmental performance, and economic development in China and Sweden, and then pointed out that governments should reform public relative environmental tax policy, especially regarding carbon taxes [47]. In terms of specific environmental taxes, Chen et al. pointed out the energy saving and emission reduction effects of the carbon tax surpasses that of the energy tax in Guangdong, China. [48]. Freire-Gonzalez et al. found that only taxing the production of electricity by coal, oil, and natural gas can be better for the environment and economy than taxing all forms of electricity production in a revenue-neutral context though a dynamic computable general equilibrium model for Spain [49]. Besides, a few literature studies focused on the analysis of differences in the international environmental tax system and put forward some useful experience for environmental tax reform. Zhang et al. advised that carbon tax should be combined with domestic and foreign environmental protection tools on the basis of acknowledging the role of carbon tax in reducing emissions [50]. Wang et al. made a case study of Hebei Province in China, which provides empirical data for environmental tax reform [51]. In the same year, Zhang et al. pointed out that integrated policy mixes can perform better than carbon tax alone and proposed several suggestions regarding how to design China's carbon tax [52].

2.2. Research Hypothesis

An environmental tax is an economic means of internalizing environmental costs of environmental pollution and ecological destruction into production costs and market prices, and then distributing environmental resources through market mechanisms. Generally speaking, the environmental tax can be subdivided according to whether the object of taxation is a direct pollutant or a product that may cause pollution. The former includes carbon taxes, sulphur taxes, sewage treatment taxes, and garbage taxes. The latter is mainly for high-polluting and high-energy-consuming products, such as coal, petroleum, automobiles, and so on. The environmental tax under different divisions aims at energy saving and emission reduction, and follows the principle of "polluter pays". Welfare economists believe that the difference between the environmental pollution "pollution correction benefit" and the implementation cost "basic welfare loss" is the net environmental benefit, which can be called the "basic welfare effect"; that is, the environmental tax "green dividend". In reality, the positive incentive mechanism of an environmental tax is conducive to playing its guiding role in pollution reduction. Compared with other means and policies of environmental governance, the path of an environmental tax to achieving energy saving as well as emission reduction and environmental protection has its own characteristics, mainly reflected in the following three aspects, as shown in Part 1 of Figure 1 below.

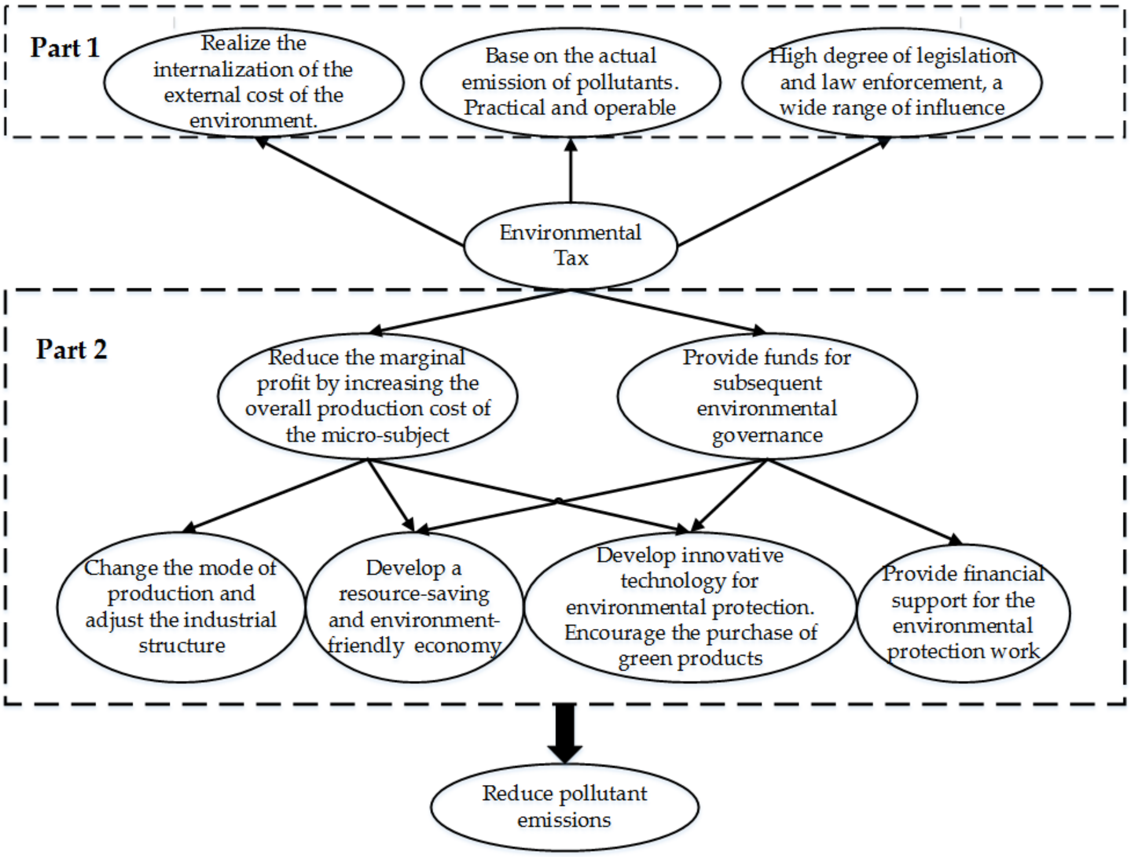

Figure 1. Characteristics of environmental tax and transmission mechanism of pollutant emission reduction.

Firstly, an environmental tax directly realizes the internalization of the external cost of the environment. Compared with general environmental regulation tools, an environmental tax directly increases the cost of production of market economy subjects and then reduces their profit margins, forcing economic subjects with high energy consumption, high emissions, and high pollution to adopt effective means to develop green production. Secondly, the environmental tax is based on the actual emission of pollutants, which is practical and operable. Some western countries implement emission rights and carbon emission trading as economic incentive environmental regulation tools based on the total amount of pollutant emissions in the future. The difficulty of operation mainly focuses on how to determine the total amount of pollutant emissions and how to control the market economy subjects that do not meet the pollution standards. The environmental tax is levied on the basis of actual sewage discharge, and it is levied on the environmental pollution behavior of most economic entities, which makes up for the deficiency of general economic incentive environmental regulation means. Thirdly, the legislation and enforcement of environmental tax are stronger and its influence is wider. Compared with the administrative means of environmental regulation, environmental taxes in most countries have established the specific content and rules of environmental tax implementation through legislative means, such as the object of tax collection, tax rate, tax reduction, and return mechanism. While realizing the standard of quantitative collection, defining the process of collection, and assessing the effect of collection, an environmental tax provides strong legal support for the relevant government administrative departments to carry out the special improvement work of environmental governance.

In addition, as an economic incentive environmental regulation tool, an environmental tax will play a greater role in promoting energy conservation and emission reduction. On the one hand, an environmental tax levied by the government internalizes the social and economic costs of environmental pollution, and reduces the marginal profit by increasing the overall production cost of the micro-subject, encouraging people to change the past mode of production and operation, carry out research and development of innovative technology for environmental protection, and develop a resource-saving economy. Reduction of polluting behavior and polluting products effectively curbs environmental degradation and promotes energy conservation and emission reduction. On the other hand, an environmental tax is levied to provide funds for subsequent environmental governance. As we all know, energy saving and emission reduction is a long-term environmental protection task with large capital demand [11,13,53] and high technical requirements, which requires a lot of manpower, materials, and financial resources. Developed countries, such as the United States and Australia, use environmental tax revenue to set up special environmental protection funds. Specialized for environmental taxation, an environmental tax not only realizes the scientific expenditure and effective supervision of special funds for environmental governance, but also provides strong financial support for the government's energy conservation and environmental protection work. In addition, the government can encourage market micro-players to carry out a technological transformation, eliminate backward production capacity, adjust industrial structures, develop energy-saving and emission-reduction technologies, and purchase green environmental protection products by means of environmental tax incentives, such as tax exemption and tax return. The transmission mechanism of environmental tax to reduce pollutant emission is shown in Part 2 of Figure 1 below.

Based on this, this paper proposes the following research hypotheses:

Hypothesis 1. *Under the same conditions, the environmental taxes of OECD member countries can effectively reduce atmospheric pollutants, such as carbon dioxide and sulfur dioxide.*

Hypothesis 2. *Under the same conditions, the quasi-environmental taxes of China's provinces can effectively reduce the "three wastes" pollutants.*

3. Materials and Methods

3.1. Sample Selection and Data Sources

The main research samples include: per capita environmental taxes, greenhouse gas emissions, carbon dioxide emissions, sulfur oxides, and nitrogen oxide emissions of 35 OECD member countries from 1994 to 2016; per capita quasi-environmental tax, sulfur dioxide emissions, industrial solid waste production, ammonia nitrogen emissions, and chemical oxygen demand from wastewater of 31 Chinese inland provinces from 2004 to 2016. The control variables are related to data of population, per capita crude oil consumption, per capita coal consumption, annual growth rate of GDP, and industrial added value for the two research subjects. Among them, there are 805 valid observations of OECD member countries and 403 of Chinese provinces. All of the data in this paper were obtained from the OECD database, British Petroleum(BP), and the Chinese National Bureau of Statistics database.

3.2. Variable Interpretations

Considering the availability of data, the measurement indicators of environmental tax emission reduction effect and time range selected for the two research subjects are different. However, the indicators used can reflect the main environmental problems and environmental governance priorities of the research objects, which can better measure the overall emission reduction effects of an environmental tax on each research object. In addition, due to the lack of data in Chinese provinces before 2004 and the fact that the time of collecting environment-related taxes in China is later than that in OECD countries, it is reasonable to shorten the time range of China's research. The specific explanation of each variable is shown in Table 2.

In order to avoid the influence of variable measurement unit and order of magnitude difference on the experimental results, the logarithm or per capita number of selected variables are unified in this paper. Compared with cross-sectional data and time series data, panel data increases sample observations, which can obtain more dynamic information of the object of study, and are more suitable for multi-agent comparative analysis.

Table 2. Explanation of variables.

Variable	Symbol	Definition of Variables
Organization for Economic Cooperation and Development environmental tax	ET_OC	The per capita environmental taxes of 35 OECD countries. The unit is $10,000/person
China environmental tax	ET_CN	The per capita quasi-environmental taxes of 31 provinces in China. The unit is 10,000 yuan/person
Greenhouse gas emissions	GHE_OC	Logarithm of total greenhouse gas emissions from OECD member countries
Carbon dioxide emissions	CO_2_OC	Logarithm of total CO2 emissions from OECD member countries
Sulfur oxide emissions	SO_OC	Logarithm of total sulfur oxide emissions from OECD member countries
Nitrogen oxide emission	NO_OC	Logarithm of total nitrogen oxide emission from OECD member countries
Sulfur dioxide emissions	SO_2_CN	Logarithm of total sulfur dioxide emissions from Chinese provinces
Industrial solid waste production	SW_CN	Logarithm of Industrial Solid Waste Production from Chinese provinces
Ammonia nitrogen emission from wastewater	AN_CN	The per capita discharge of ammonia nitrogen from wastewater of Chinese provinces. The unit is per ton/person.
Chemical oxygen demand from wastewater	COD_CN	The per capita chemical oxygen demand from wastewater of Chinese provinces. The unit is per ton/person.
OECD population	OP_OC	The logarithm of the population of the OECD member countries
China population	OP_CN	The logarithm of the population of Chinese provinces
OECD per capita crude oil consumption	OIL_OC	The per capita crude oil consumption of OECD member countries. The unit is per ton/person
China per capita crude oil consumption	OIL_CN	The per capita crude oil consumption of Chinese provinces. The unit is per ton/person
OECD per capita coal consumption	CA_OC	The per capita coal consumption of OECD member countries. The unit is per ton/person
China per capita coal consumption	CA_CN	The per capita coal consumption of Chinese provinces. The unit is per ton/person
OECD GDP growth rate	GDP_OC	Annual growth rate of GDP of OECD member countries
China GDP growth rate	GDP_CN	Annual growth rate of GDP of Chinese provinces
OECD industrial added value	IND_OC	Ratio of industrial added value to GDP of OECD member countries
China industrial added value	IND_CN	Ratio of industrial added value to GDP of Chinese provinces

3.3. Research Model

According to the data characteristics of the selected variables, this paper selects the panel Auto-Regressive Distributed Lag Modelling Approach (ARDL) for research, which was first introduced by Pesaran et al. [54] in 1995. The selection of relevant variables refers to the existing literature (Bruvoll et al. [25], Nerudova et al. [27], He et al. [31], Rapanos et al. [32]). The panel ARDL model does not limit the sample size, and takes full advantage of the lag period to show the long-term and short-term regression relationship between variables. Moreover, compared with the general linear regression model, panel ARDL is helpful in overcoming the endogenous problem among variables.

Therefore, in order to verify the emission reduction effect of an environmental tax in OECD countries and provinces of China, and to compare the differences of emission reduction effects under different circumstances, this paper respectively establishes research Equations (1) and (2) for Hypothesis 1 and 2.

$$\begin{aligned}\Delta LogGHE\_OC_{it} = \; & \alpha_i + \sum_{j-1}^{m-1} \beta_{ij} \Delta LogGHE\_OC_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il} \Delta ET\_OC_{i,t-l} \\ & + \sum_{k=0}^{q-1} \mu_{ik} \Delta \mathrm{Log}OP\_OC_{i,t-k} + \sum_{r=0}^{p-1} \gamma_{ir} \Delta OIL\_OC_{i,t-r} \\ & + \sum_{s=0}^{u-1} \chi_{is} \Delta CA\_OC_{i,t-s} + \sum_{w=0}^{d-1} \omega_{iw} \Delta GDP\_OC_{i,t-w} \\ & + \sum_{b=0}^{f-1} \upsilon_{ib} \Delta IND\_OC_{i,t-b} + \delta_1 LogGHE\_OC_{i,t-1} + \delta_2 ET\_OC_{i,t-1} \\ & + \delta_3 LogOP\_OC_{i,t-1} + \delta_4 OIL\_OC_{i,t-1} + \delta_5 CA\_OC_{i,t-1} + \delta_6 GDP\_OC_{i,t-1} \\ & + \delta_7 IND\_OC_{i,t-1} + \delta_8 ECT_{i,t-1} + \varepsilon_{1i,t}\end{aligned} \tag{1}$$

$$\begin{aligned}\Delta LogSO_2\_CN_{it} = \; & \alpha_i + \sum_{j-1}^{m-1} \beta_{ij} \Delta LogSO_2\_CN_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il} \Delta ET\_CN_{i,t-l} \\ & + \sum_{k=0}^{q-1} \mu_{ik} \Delta LogOP\_CN_{i,t-k} + \sum_{r=0}^{p-1} \gamma_{ir} \Delta OIL\_CN_{i,t-r} \\ & + \sum_{s=0}^{u-1} \chi_{is} \Delta CA\_CN_{i,t-s} + \sum_{w=0}^{d-1} \omega_{iw} \Delta GDP\_CN_{i,t-w} \\ & + \sum_{b=0}^{f-1} \upsilon_{ib} \Delta IND\_CN_{i,t-b} + \delta_1 LogSO_2\_CN_{i,t-1} + \delta_2 ET\_CN_{i,t-1} \\ & + \delta_3 LogOP\_CN_{i,t-1} + \delta_4 OIL\_CN_{i,t-1} + \delta_5 CA\_CN_{i,t-1} + \delta_6 GDP\_CN_{i,t-1} \\ & + \delta_7 IND\_CN_{i,t-1} + \delta_8 ECT_{i,t-1} + \varepsilon_{1i,t}\end{aligned} \tag{2}$$

The dependent variable in Equation (1) is the logarithm of total greenhouse gas emissions (GHE_OC) of OECD countries, and the independent variable is the per capita environmental tax (ET_OC). The control variables are the logarithm of population (OP_OC), the per capita crude oil consumption (OIL_OC), per capita coal consumption (CA_OC), the annual growth rate of GDP (GDP_OC), and the ratio of industrial added value to GDP (IND_OC) of OECD member countries. In order to simplify the description of the model, with the independent variable ET_OC and control variables unchanged in Equation (1), GHE_OC is replaced by the logarithms of the total carbon dioxide emissions (CO_2_OC), total sulfur oxide emissions (SO_OC), and total nitrogen oxide emissions (NO_OC) in turn, and then the research equations investigating the effects of OECD environmental tax reduction can be obtained one by one.

The dependent variable in Equation (2) is the logarithm of total sulfur dioxide emissions (SO_2_CN) of Chinese provinces, the independent variable is the per capita quasi-environmental tax (ET_CN), and the control variables are the logarithm of population (OP_CN), the per capita crude oil consumption (OIL_CN), per capita coal consumption (CA_CN), the annual growth rate of GDP (GDP_CN), and the ratio of industrial added value to GDP (IND_CN) of Chinese provinces. In order to simplify the space, with the independent variable ET_CN and some control variables Equation (2) remaining unchanged, SO_2_CN is replaced by three variables in turn: logarithm of industrial solid waste production (SW_CN), ammonia nitrogen discharge per capita (AN_CN), and chemical oxygen demand per capita (COD_CN), so as to obtain the research models for investigating the effects of environmental taxes reduction in Chinese provinces one by one. Considering that the environmental performance of an environmental tax restraining the discharge of major pollutants, such as gas pollutants, industrial solid wastes, and wastewater, may lag behind, and in order to avoid the endogenous problem of variable data, this paper will deal with the independent variables ET_OC and ET_CN with a lag period. Furthermore, considering the long-term and arduous nature of China's sewage treatment work, environmental taxes with a lag of one, two, and three phases were added to the research model to reflect the effect of environmental taxes on reducing the major pollutants of wastewater in Chinese provinces.

In Equation (1), β is the short-term autoregressive coefficient of dependent variable GHE_OC and φ is the short-term regression coefficient between independent variable ET_OC and GHE_OC. According to hypotheses H1, φ should be negative. Here, μ, γ, χ, ω, and ν are the short-term regression coefficients between the control variables and GHE_OC. For example, μ represents the short-term regression relationship between the control variable OP_OC and GHE_OC; δ_1 is the long-term autoregressive coefficient of GHE_OC and δ_2 is the long-term regression coefficient between ET_OC and GHE_OC.

According to hypotheses H1, δ_2 should be negative, too. The long-term regression coefficients between control variables and GHE_OC are δ_3 to δ_7, respectively. For example, δ_3 represents the long-term regression relationship between control variable OP_OC and dependent variable GHE_OC.

Similarly, in Equation (2), β is the short-term autoregressive coefficient of dependent variable SO_2_CN and φ is the short-term regression coefficient between independent variable ET_CN and SO_2_CN. According to hypotheses H2, φ should be negative. Here, μ, γ, χ, ω, and ν are the short-term regression coefficients between the control variables and SO_2_CN. For example, μ represents the short-term regression relationship between the control variable OP_CN and SO_2_CN; δ_1 is the long-term autoregressive coefficient of SO_2_CN and δ_2 is the long-term regression coefficient between ET_CN and SO_2_CN. According to hypotheses H2, δ_2 should be negative, too. The long-term regression coefficients between control variables and SO_2_CN are δ_3 to δ_7, respectively. For example, δ_3 represents the long-term regression relationship between control variable OP_CN and dependent variable SO_2_CN.

In both Equations (1) and (2), each variable is followed by two subscripts (such as i and t of GHE_OC_{it}, as well as i and t-l of $ET\_OC_{i,t\text{-}l}$ in Equation (1)). The first subscript represents a research object in panel data, and the second subscript represents the number of lag periods of the variable. Here, Δ and $\varepsilon_{ki,t}$ (k = 1, 2, 3, ...) are the first order difference term and white noise term of each variable, respectively, while Log presents the logarithm of the variable. In addition, α_i is the intercept term for different countries and the subscript i indicates the change from 1 to N for a particular study subject. ECT is the Error Correction Term, so δ_8 presents the error correction term coefficient.

4. Empirical Results

4.1. Descriptive Statistics

Table 3 is the descriptive statistics of the variables studied in this paper. It can be found that the average, median, maximum, and minimum values of quasi-environmental taxes in China are higher than the indicators of OECD environmental taxes, indicating the intensity of environmental taxes in Chinese provinces is stronger than in OECD countries. The standard deviation of each variable is small, which further shows that logarithm and average value can eliminate data volatility.

Table 3. Descriptive Statistics.

Variable	Mean	Median	Maximum	Minimum	Standard Deviation
ET_OC	0.0795	0.0754	0.2485	−0.0236	0.0447
ET_CN	0.1670	0.1268	1.2133	0.0023	0.1620
GHE_OC	8.1377	7.9624	9.8664	6.5226	0.6680
CO_2_OC	8.0272	7.8721	9.7876	6.3733	0.6722
SO_OC	5.2016	5.1663	7.2867	2.9996	0.8231
NO_OC	5.5192	5.3750	7.3551	4.2977	0.6312
SO_2_CN	5.6596	5.7664	6.3015	3.0000	0.5580
SW_CN	7.6532	7.7614	8.6587	4.7393	0.5908
AN_CN	0.0014	0.0013	0.0028	0.0003	0.0005
COD_CN	0.0134	0.0119	0.0411	0.0040	0.0068
OP_OC	3.1014	3.0155	4.5096	1.4265	0.6661
OP_CN	3.5124	3.5769	4.0414	2.4409	0.3721
OIL_OC	1.7579	1.6323	6.9588	0.3970	0.9738
OIL_CN	0.4112	0.3075	1.6119	0.0000	0.3706
CA_OC	0.7254	0.5095	3.3498	0.0128	0.6396
CA_CN	3.1311	2.4495	14.7068	0.3901	2.6297
GDP_OC	0.0277	0.0283	0.2556	−0.1472	0.0316
GDP_CN	0.1468	0.1477	0.3227	−0.2240	0.0676
IND_OC	0.2887	0.2870	0.4490	0.1200	0.0576
IND_CN	0.4623	0.4807	0.5905	0.1926	0.0821

4.2. Stationarity and Co-Integration Test

To avoid regression errors, the unit root test must be performed on the panel data before the regression. This paper selects four panel unit root test methods: Levin-Lin-Chu Test (LLC), Im-Pesaran-Shin Test (IPS), Augmented Dickey-Fuller Fisher Test (ADF), and Phillips-Perron Fisher Test (PP). Table 4 shows the results of panel unit root tests for each variable. Level represents the original sequence and "Difference" is the corresponding first-order difference sequence. The original sequence and the first-order difference sequence of ET_OC, SW_CN, OIL_OC, CA_OC, CA_CN, and GDP_OC reject the original hypothesis of the unit root under the four methods, indicating that the variables are stable. The remaining variables are stable under at least one method, and the first-order difference sequences are all stable.

Table 4. Unit Root Test.

Variable	Levin-Lin-Chu Test		Im-Pesaran-Shin Test		Augmented Dickey-Fuller Fisher Test		Phillips-Perron Fisher Test	
	Level	Difference	Level	Level	Level	Difference	Level	Difference
ET_OC	−4.094 *** (0.000)	−18.437 *** (0.000)	−1.721 ** (0.043)	−16.693 *** (0.000)	88.417 * (0.068)	378.914 *** (0.000)	94.562 ** (0.027)	407.408 *** (0.000)
ET_CN	−3.042 *** (0.001)	−6.341 *** (0.000)	0.194 (0.577)	−4.135 *** (0.000)	63.388 (0.427)	117.223 *** (0.000)	75.845 (0.111)	114.712 *** (0.000)
GHE_OC	−1.792 ** (0.037)	−19.347 *** (0.000)	0.894 (0.814)	−19.368 *** (0.000)	78.183 (0.235)	448.848 *** (0.000)	72.703 (0.389)	568.124 *** (0.000)
CO_2_OC	−4.034 *** (0.000)	−20.743 *** (0.000)	−0.511 (0.305)	−19.474 *** (0.000)	89.488 * (0.058)	448.973 *** (0.000)	87.200 * (0.080)	574.826 *** (0.000)
SO_OC	−1.857** (0.032)	−16.562 *** (0.000)	4.252 (1.000)	−16.760 *** (0.000)	64.935 (0.583)	378.567 *** (0.000)	76.734 (0.219)	475.911 *** (0.000)
NO_OC	−1.970 ** (0.024)	−17.138 *** (0.000)	0.667 (0.748)	−15.662 *** (0.000)	60.426 (0.732)	362.691 *** (0.000)	48.392 (0.966)	425.889 *** (0.000)
SO_2_CN	−6.051 *** (0.000)	−7.007 *** (0.000)	11.415 (1.000)	2.223 (0.987)	97.685 *** (0.003)	98.301 *** (0.002)	104.937 *** (0.001)	97.475 *** (0.003)
SW_CN	−9.693 *** (0.000)	−9.912 *** (0.000)	−2.530 *** (0.006)	−5.381 *** (0.000)	95.634 (0.004)	130.380 *** (0.000)	155.443 *** (0.000)	141.828 *** (0.000)
AN_CN	−1.876 ** (0.030)	−9.683 *** (0.000)	−0.505 (0.307)	−6.619 *** (0.000)	44.967 (0.949)	142.921 *** (0.000)	44.214 (0.957)	143.788 *** (0.000)
COD_CN	−4.003 *** (0.000)	−5.125 *** (0.000)	0.213 (0.584)	−4.704 *** (0.000)	61.429 (0.497)	110.998 *** (0.000)	61.171 (0.506)	112.548 *** (0.000)
OP_OC	−2.301 ** (0.011)	−1.615 * (0.053)	−2.771 *** (0.003)	−3.874 (0.000)	99.090 ** (0.013)	137.653 *** (0.000)	52.156 (0.945)	151.421 *** (0.000)
OP_CN	−5.647 *** (0.000)	−10.215 *** (0.000)	−0.551 (0.291)	−4.875 *** (0.000)	118.675 *** (0.000)	137.347 *** (0.000)	129.253 *** (0.000)	159.735 *** (0.000)
OIL_OC	−1.781 ** (0.038)	−14.828 *** (0.000)	−1.612 * (0.053)	−16.249 *** (0.000)	94.434 ** (0.028)	375.703 *** (0.000)	96.353 ** (0.020)	538.516 *** (0.000)
OIL_CN	−1.404 * (0.080)	−10.862*** (0.000)	1.664 (0.952)	−8.078 *** (0.000)	50.639 (0.677)	178.559 *** (0.000)	40.457 (0.942)	192.515 *** (0.000)
CA_OC	−1.657 ** (0.049)	−18.171 *** (0.000)	−2.061 ** (0.020)	−20.509 *** (0.000)	110.571 *** (0.001)	485.474 *** (0.000)	336.692 *** (0.000)	645.815 *** (0.000)
CA_CN	−5.924 *** (0.000)	−9.624 *** (0.000)	−2.599 *** (0.005)	-5.043 *** (0.000)	103.148 *** (0.001)	119.004 *** (0.000)	115.306 *** (0.000)	117.498 *** (0.000)
GDP_OC	−14.658 *** (0.000)	−27.507 *** (0.000)	−11.982 *** (0.000)	−26.708 *** (0.000)	269.917 *** (0.000)	622.602 *** (0.000)	281.475 *** (0.000)	1856.240 *** (0.000)
GDP_CN	−7.259 *** (0.000)	−21.175 *** (0.000)	−1.684 ** (0.046)	−15.116 *** (0.000)	75.325 (0.119)	302.083 *** (0.000)	74.487 (0.133)	483.826 *** (0.000)
IND_OC	−2.453 *** (0.007)	−20.392 *** (0.000)	−0.634 (0.263)	−18.709 *** (0.000)	77.168 (0.209)	415.356 *** (0.000)	85.768 * (0.072)	714.207 *** (0.000)
IND_CN	−6.013 *** (0.000)	−8.469 *** (0.000)	7.394 (1.000)	−3.669 (0.000)	119.329 *** (0.000)	110.670 *** (0.000)	97.010 *** (0.003)	106.965 *** (0.000)

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

The results of unit root tests lay a foundation for a further co-integration test. A co-integration test reflects the co-integration relationship among variables, which is used to understand the long-term dynamic relationship among variables. In this paper, three panel co-integration testing methods, Kao, Panel Phillips-Perron (PP) and Panel Augmented Dickey-Fuller (ADF), are selected. The original hypothesis for them is that there is no co-integration relationship between variables. Table 5 shows the results of panel data co-integration tests of OECD member countries and provinces of China. The Kao test statistic, the revised *p* value, and the ADF statistic value of the related variable groups all rejected the original hypothesis, indicating that there was a long-term co-integration relationship between variables.

Table 5. Co-integration test results.

Research Object	Variable	Kao Test	Phillips-Perron Test	Augmented Dickey-Fuller Test
OECD	GHE_OC	−1.7271 ** (0.042)	−3.2083 *** (0.001)	−4.0642 *** (0.000)
	CO_2_OC	−1.3772 * (0.084)	−3.6991 *** (0.000)	−4.6329 *** (0.000)
	SO_OC	−2.4946 *** (0.006)	−2.1843 ** (0.015)	−2.3829 *** (0.009)
	NO_OC	−3.5177 *** (0.000)	−3.8141 *** (0.000)	−6.0507 *** (0.000)
China	SO_2_CN	−1.3666 * (0.086)	−7.6017 *** (0.000)	−7.3308 *** (0.000)
	SW_CN	−1.6079 * (0.054)	−7.8340 *** (0.000)	−4.1186 *** (0.000)
	AN_CN	−2.3764 *** (0.009)	0.7597 (0.776)	0.1426 (0.557)
	COD_CN	−2.1653 ** (0.015)	−2.2676 ** (0.012)	−2.9294 *** (0.002)

Note: *p*-values are reported in parentheses below T-Statistics. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

4.3. Overall Regression Results

Tables 6 and 7 show the long-term and short-term dynamic relationships between the environmental taxes of OECD member countries, quasi-environmental taxes of Chinese provinces, and their pollutants base on the panel ARDL. Overall, the OECD and China's environmental taxes have achieved certain emission reduction effects, but the intensity of emission reduction for specific pollutants is different.

Firstly, the emission reduction effect of an environmental tax in OECD member countries from 1994 to 2016 is analyzed, as shown in Table 6. Since OECD member countries have set strict emission standards for solid waste, domestic garbage, and industrial and domestic wastewater, the gases emitted from production and living are currently the main sources of pollution. It is reasonable to use the gas index to measure the OECD environmental tax reduction effects. Among the four types of gas pollutants investigated, the environmental tax of the OECD has the strongest inhibition on greenhouse gases, followed by the reduction of nitrogen oxides. From the short-term emission reduction effect of OECD environmental taxes on gaseous pollutants, the regression coefficients between OECD environmental taxes and original as well as lag one phase sequences of greenhouse gases are −0.023 and −0.025, respectively, which are significant at the levels of 10% and 5%, respectively. That is, the environmental taxes increase by 1%, resulting in a significant reduction of 0.023% in greenhouse gas emissions in the current period and a decrease of 0.025% in the first lag period. There are negative correlations between OECD environmental taxes and carbon dioxide's lag one period, both for the original sequence and lag one period of sulfur oxide, but they are not significant. In addition, the short-term coefficient of the environmental tax and the original sequence of nitrogen oxides is negative and significant at the

1% level, that is, the environmental taxes increase of 1% leads to a significant reduction of nitrogen oxide emissions of 0.057% in the current period. Regarding the long-term emission reduction effect of OECD environmental taxes on gaseous pollutants, the long-term coefficients between environmental taxes and greenhouse gases, carbon dioxide is negative but not significant, indicating that the OECD environmental taxes have a certain degree of inhibition on gas emissions in the long run, but they must adhere to the environmental tax policies for a long time and continuously optimize and adjust these. Besides, there is a significant positive correlation between population size and carbon dioxide emissions in the long and short term. The annual growth rate of GDP has a significant positive correlation with greenhouse gas, carbon dioxide, and nitrogen oxide emissions at the same time, which indicates that population and economic growth are closely related to gas emissions.

Table 6. Panel ARDL regression results of OECD environmental tax reduction effects.

Variable	GHE_OC		CO_2_OC		SO_OC		NO_OC	
	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period
LAG	−0.013 *** (0.005)	−1.016 *** (0.000)	−0.041 *** (0.000)	−1.002 *** (0.000)	−0.004 (0.573)	−0.829 *** (0.000)	−0.003 (0.495)	−0.857 *** (0.000)
D_ET_OC	−0.008 (0.919)	-0.005 (0.953)	−0.056 (0.551)	−0.039 (0.690)	0.143 (0.732)	0.118 (0.779)	0.139 (0.290)	0.113 (0.386)
L1_ET_OC	−0.023 * (0.058)	−0.025 ** (0.048)	0.005 (0.724)	−0.007 (0.640)	−0.114 (0.130)	−0.078 (0.232)	−0.057 *** (0.005)	−0.033 (0.101)
D_OP_OC	0.958 *** (0.000)	0.961 *** (0.000)	0.982 *** (0.000)	1.150 *** (0.000)	3.596 *** (0.000)	2.596 *** (0.003)	1.296 *** (0.000)	1.183 *** (0.000)
D_OIL_OC	0.067 *** (0.000)	0.068 *** (0.000)	0.082 *** (0.000)	0.083 *** (0.000)	0.049 * (0.057)	0.049 * (0.062)	0.088 *** (0.000)	0.091 *** (0.000)
D_CA_OC	0.122 *** (0.000)	0.129 *** (0.000)	0.141 *** (0.000)	0.150 *** (0.000)	0.275 *** (0.000)	0.295 *** (0.000)	0.069 *** (0.000)	0.076 *** (0.000)
D_GDP_OC	0.134 *** (0.000)	0.129 *** (0.000)	0.145 *** (0.000)	0.148 *** (0.000)	0.001 (0.995)	0.021 (0.821)	0.145 *** (0.000)	0.151 *** (0.000)
D_IND_OC	−0.018 (0.603)	−0.021 (0.550)	−0.029 (0.486)	−0.053 (0.237)	0.338 * (0.065)	0.101 (0.608)	−0.044 (0.442)	−0.145 ** (0.017)
L1_OP_OC	0.013 *** (0.004)	0.001 (0.384)	0.043 *** (0.000)	0.002 ** (0.012)	−0.001 (0.879)	−0.003 (0.364)	0.001 (0.719)	-0.001 (0.479)
L1_OIL_OC	0.003 *** (0.001)	0.001 (0.154)	0.007 *** (0.000)	0.000 (0.798)	0.003 (0.396)	0.003 (0.418)	0.000 (0.686)	-0.001 (0.430)
L1_CA_OC	0.001 (0.200)	−0.001 (0.218)	0.007 *** (0.000)	−0.001 (0.306)	0.006 (0.124)	0.005 (0.174)	−0.00009 (0.945)	0.00001 (0.995)
L1_GDP_OC	0.110 *** (0.000)	0.112 *** (0.000)	0.120 *** (0.000)	0.138 *** (0.000)	0.010 (0.911)	−0.016 (0.857)	0.114*** (0.000)	0.087*** (0.003)
L1_IND_OC	0.008 (0.358)	0.007 (0.413)	0.010 (0.370)	−0.008 (0.480)	−0.025 (0.571)	−0.022 (0.617)	0.011 (0.447)	0.003 (0.854)
_cons	0.055 ** (0.016)	−0.007 * (0.080)	0.174 *** (0.000)	−0.008 (0.119)	−0.007 (0.790)	−0.013 (0.530)	−0.002 (0.874)	−0.006 (0.327)

Note: p-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Next, we analyze the emission reduction effect of quasi-environmental taxes of China from 2004 to 2016, as shown in Table 7. As a medium- and high-speed developing economy, China's environmental problems are general and diversified. The use of "three wastes" can more comprehensively measure China's quasi-environmental tax reduction effects. Overall, the environmental taxes have a significant effect on suppressing the "three wastes" in the short term, and it is necessary to further strengthen the emission reduction effect in the long run. In the short term, the regression coefficients between Chinese quasi-environmental taxes and original as well as lag one phase sequences of sulfur dioxide emissions are -0.139 and -0.108, respectively, which are both significant at the levels of 1%, respectively. That is to say, the environmental taxes increase by 1%, resulting in a significant reduction of 0.139% in sulfur dioxide emissions in the current period and a decrease of 0.108% in the first lagging period. The short-term negative correlation between environmental taxes and industrial solid waste production is also significant, which shows that environmental taxes increase by 1%, while industrial solid waste production decreases by 0.053% in the current period and 0.061% in the lagging period. The short-term emission reduction effect of China's quasi-environmental taxes on major pollutants from wastewater is different. The environmental taxes have a significantly better effect on the reduction of chemical oxygen demand in wastewater than ammonia nitrogen. The first and third lagging environmental taxes can significantly reduce chemical oxygen demand (COD) of wastewater in the present and the first lag period. Specifically, the increase of 1% of the environmental taxes in the first lag period resulted in significant decreases of 0.018% and 0.017% of COD in the present and the first lag period, respectively. The increase of 1% of the environmental taxes in the third lag period resulted in significant decreases of 0.077% and 0.075% of COD in the present and the first lag period, respectively. However, the short-term regression relationship between lagging environmental taxes and ammonia nitrogen emission of wastewater is negative but not significant, while the increase of 1% of the environmental taxes in the third lag period resulted in a significant decrease of 0.006% and 0.005% of ammonia nitrogen emissions in the present and the first lag period, respectively. In the long run, the effect of Chinese quasi-environmental taxes on the emission reduction of "three wastes" pollutants is still not obvious. It is necessary to further formulate and implement long-term effective environmental policies to promote environmental performance of environmental taxes. Moreover, there is a significant positive correlation between economic growth and the production of industrial solid waste, ammonia nitrogen emissions, as well as chemical oxygen demand from wastewater in the long and short term, indicating that economic growth is closely related to the discharge of "three wastes" pollutants, so it is necessary to pay attention to environmental issues in the process of national economic development. The short-term regression relationship between industrial added value and sulfur dioxide, ammonia nitrogen emissions, and chemical oxygen demand is positive, while the long-term regression relationship is significantly negative, indicating that the industrialization process will inevitably produce environmental pollution problems, but with the adjustment of industrial structure and industrial transformation and upgrades, the environmental problems encountered in economic development will be solved one by one.

Comparing the overall emission reduction effect of OECD and Chinese environmental taxes, it is found that both have good comprehensive emission reduction effects. For similar pollutants, such as sulfur dioxide, China's environmental tax emission reduction effect is slightly better than the OECDs. In terms of the sustainability of the environmental tax reduction effect, OECD environmental taxes not only significantly reduce greenhouse gas emissions in the short term, but also have a negative correlation with air pollutants in the long term. Furthermore, on the premise of affirming the overall emission reduction effect of environmental taxes, considering that the OECD is a multi-cultural and wide-ranging economy, China is a vast country with great regional differences, are there significant differences or similarities in the emission reduction effects of environmental taxes among OECD member countries and Chinese provinces under different tax collection and management environments, industrial structures, and economic development levels? Therefore, this paper divides 35 OECD countries and 31 inland Chinese provinces into groups according to the scale of environmental tax collection, industrial added value, and economic development level to further explore the emission reduction effect of OECD and Chinese environmental taxes under different groups and the heterogeneity of the emission reduction effect of the two research objects.

Table 7. Panel ARDL regression results of China quasi-environmental tax reduction effects.

Variable	SO_2_CN		SW_CN		AN_CN		COD_CN	
	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period
LAG	−0.029 (0.265)	−0.848 *** (0.000)	−0.020 (0.180)	−1.115 *** (0.000)	−0.230 *** (0.000)	−1.148 *** (0.000)	−0.172 *** (0.000)	−1.205 *** (0.000)
D_ET_CN	0.273 * (0.068)	0.419 *** (0.006)	0.080 (0.544)	0.107 (0.438)	0.002 *** (0.002)	0.002 *** (0.000)	0.018 ** (0.032)	0.022 ** (0.012)
L1_ET_CN	−0.139 *** (0.000)	−0.108 *** (0.003)	−0.053 * (0.071)	−0.061 ** (0.048)	−0.0004 (0.611)	−0.0003 (0.676)	−0.018 * (0.073)	−0.017* (0.091)
L2_ET_CN					0.006 *** (0.000)	0.005 *** (0.000)	0.089 *** (0.000)	0.086 *** (0.000)
L3_ET_CN					−0.006 *** (0.000)	−0.005 *** (0.000)	−0.077 *** (0.000)	−0.075 *** (0.000)
D_OP_CN	−0.756 (0.359)	−0.316 (0.735)	−0.488 (0.484)	−0.627 (0.439)	−0.007 * (0.068)	−0.007 * (0.098)	−0.088 * (0.082)	−0.064 (0.206)
D_OIL_CN	0.057 (0.302)	0.052 (0.344)						
D_CA_CN	0.018 (0.177)	0.014 (0.303)	0.037 *** (0.002)	0.042 *** (0.001)				
D_GDP_CN	−0.055 (0.577)	0.016 (0.877)	0.278 *** (0.001)	0.278 *** (0.002)	0.001 *** (0.001)	0.002 *** (0.000)	0.020 *** (0.000)	0.024 *** (0.000)
D_IND_CN	0.778 ** (0.023)	0.344 (0.338)	0.198 (0.467)	0.188 (0.524)	−0.003 ** (0.031)	−0.003 * (0.053)	−0.034 * (0.066)	−0.032* (0.090)
L1_OP_CN	0.0003 (0.993)	−0.015 (0.341)	−0.020 (0.274)	−0.039 *** (0.006)	−0.00005 (0.382)	0.00002 (0.761)	−0.001 (0.273)	0.0001 (0.869)
L1_OIL_CN	0.024 * (0.067)	0.013 (0.330)						
L1_CA_CN	−0.001 (0.608)	−0.002 (0.334)	−0.001 (0.783)	−0.002 (0.251)				
L1_GDP_CN	0.287 ** (0.011)	0.304 *** (0.008)	0.264 *** (0.006)	0.313 *** (0.002)	0.003 *** (0.000)	0.003 *** (0.000)	0.035 *** (0.000)	0.045 *** (0.000)
L1_IND_CN	0.117 * (0.098)	0.086 (0.193)	0.169 *** (0.006)	0.151 ** (0.012)	0.001 ** (0.014)	0.0002 (0.485)	0.007 ** (0.036)	0.004 (0.281)
_cons	0.053 (0.467)	−0.058 (0.336)	0.144 * (0.061)	0.071 (0.201)	0.000 (0.167)	−0.001 *** (0.001)	−0.004 (0.160)	−0.010 *** (0.001)

Note: p-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

4.4. Grouping Regression Results

4.4.1. Scale of Environmental Tax Collection

Statistics show that OECD member countries have different standards and objects of environmental tax and fee collection. Taking the vehicle traffic tax as an example, South Korea, Australia, and other countries use the price of motor vehicles and the number of cylinders as the levy standard, while Finland, Austria, and other countries set differentiated tax rates according to the intensity of motor vehicle carbon emissions. In the specific form of tax rate, Belgium adopts a fixed tax rate based on the horsepower of motor vehicles, Poland adopts a proportional tax rate based on the purchase price of vehicles, while Denmark and Canada choose a combination of fixed and proportion based on the type of motor vehicles. There are unified laws and regulations at the national level for quasi-environmental taxes, such as resource taxes, urban land use taxes, and vehicle and shipping taxes in China, but the specific collection standards and the definition of tax objects is further refined by provinces in the formal collection and management, in combination with the actual situation of the regions. Based on the above differences, OECD member countries and China's mainland provinces have different emphases on environmental tax collection and management, as well as tax burden intensity, which may lead to differences in environmental tax emission reduction effects under different collection scales.

Taking the ratio of environmental taxes to GDP as a measure of the scale of collection, this paper examines the differences of environmental tax emission reduction effects among OECD member countries and Chinese provinces. The specific method involves averaging the annual data of the ratio of environmental tax to GDP of 35 OECD countries, as well as 31 inland provinces in China, then grouping countries and provinces according to their numerical values. In other cases, the grouping method is similar. At the same time, considering the small differences in the scale of environmental taxes and the degree of economic development among the OECD member countries, combined with the characteristics of the average of the relevant data, OECD environmental tax collection scale and economic development level are divided into two groups, with 2.5% as the boundary. Tables 8 and 9 show the emission reduction effects of environmental taxes in OECD countries and Chinese provinces under different collection scales.

Table 8. ARDL regression results of environmental tax emission reduction effect in OECD member countries with different levy scales.

Variable	GHE_OC				CO_2_OC			
	Low		High		Low		High	
	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period
LAG	−0.008 (0.123)	−1.044 *** (0.000)	−0.022 * (0.087)	−0.998 *** (0.000)	−0.046 *** (0.000)	−1.017 *** (0.000)	−0.030 ** (0.034)	−1.001 *** (0.000)
D_ET_OC	0.052 (0.645)	0.059 (0.613)	−0.077 (0.504)	-0.062 (0.600)	0.034 (0.816)	0.097 (0.529)	−0.138 (0.311)	−0.112 (0.417)
L1_ET_OC	−0.055 *** (0.008)	−0.063 *** (0.003)	−0.019 (0.458)	−0.023 (0.349)	0.010 (0.696)	0.006 (0.833)	−0.022 (0.465)	−0.027 (0.345)
Control variable	Omit							
Variable	SO_OC				NO_OC			
	Low		High		Low		High	
	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period	Original Sequence	The First Lag Period
LAG	−0.014 (0.111)	−0.821 *** (0.000)	−0.002 (0.810)	−0.860 *** (0.000)	−0.005 (0.445)	−0.819 *** (0.000)	−0.010 (0.182)	−0.924 *** (0.000)
D_ET_OC	0.011 (0.988)	-0.220 (0.759)	0.518 (0.382)	0.555 (0.357)	0.182 (0.516)	0.174 (0.524)	0.082 (0.572)	0.066 (0.659)
L1_ET_OC	−0.288** (0.032)	−0.118 (0.333)	−0.084 (0.552)	−0.044 (0.728)	−0.127*** (0.008)	−0.055 (0.241)	−0.029 (0.338)	−0.022 (0.476)
Control variable	Omit							

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Table 9. ARDL regression results of environmental tax emission reduction effect in Chinese inland provinces with different levy scales.

Variable	SO_2_CN						SW_CN					
	Low		Medium		High		Low		Medium		High	
	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag
LAG	−0.097 (0.502)	−0.711 *** (0.010)	−0.112 ** (0.024)	−0.887 *** (0.000)	0.004 (0.941)	−0.917 *** (0.000)	−0.074 * (0.055)	−1.208 *** (0.000)	−0.007 (0.763)	−1.111 *** (0.000)	−0.053 * (0.098)	−1.148 *** (0.000)
D_ET_CN	0.868 (0.177)	1.289 ** (0.038)	0.061 (0.813)	0.388 (0.137)	0.204 (0.343)	0.269 (0.248)	0.289 (0.583)	0.278 (0.610)	−0.045 (0.859)	−0.044 (0.869)	0.027 (0.862)	0.063 (0.711)
L1_ET_CN	−1.179 *** (0.000)	−0.851 *** (0.003)	−0.357 *** (0.000)	−0.182 ** (0.025)	-0.054 (0.317)	−0.042 (0.445)	−0.254 * (0.098)	−0.180 (0.255)	−0.025 (0.722)	−0.036 (0.619)	−0.032 (0.359)	−0.039 (0.283)
Control variable	Omit											
Variable	**AN_CN**						**COD_CN**					
	Low		**Medium**		**High**		**Low**		**Medium**		**High**	
	Original	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**
LAG	−0.434 *** (0.001)	−1.122 *** (0.000)	−0.298 *** (0.000)	−1.171 *** (0.000)	−0.150 ** (0.037)	−1.283 *** (0.000)	−0.431 *** (0.000)	−1.134 *** (0.000)	−0.208 *** (0.001)	−1.305 *** (0.000)	−0.098 (0.165)	-1.248 *** (0.000)
D_ET_CN	0.005* (0.078)	0.007** (0.012)	0.002 (0.143)	0.002 * (0.067)	0.002 ** (0.022)	0.003 ** (0.011)	0.077 ** (0.026)	0.056 (0.127)	0.009 (0.510)	0.022 (0.145)	0.021 * (0.073)	0.023 ** (0.039)
L1_ET_CN	−0.002 (0.557)	0.002 (0.584)	0.001 (0.287)	0.001 (0.403)	−0.001 (0.274)	−0.0004 (0.732)	−0.091 ** (0.050)	−0.108 ** (0.032)	0.011 (0.485)	0.009 (0.581)	−0.023 * (0.070)	−0.016 (0.233)
L2_ET_CN	0.018** (0.011)	0.010 (0.135)	0.005 ** (0.012)	0.004 * (0.059)	0.005 *** (0.005)	0.004 ** (0.028)	0.346 *** (0.000)	0.333 *** (0.000)	0.082 *** (0.002)	0.081 *** (0.002)	0.067 *** (0.002)	0.057 *** (0.010)
L3_ET_CN	−0.016 *** (0.002)	−0.017 *** (0.003)	−0.006 *** (0.000)	−0.005 *** (0.002)	−0.004 *** (0.002)	−0.004 *** (0.003)	−0.270 *** (0.000)	−0.264 *** (0.000)	−0.096 *** (0.000)	−0.090 *** (0.000)	−0.044 *** (0.003)	−0.041 *** (0.006)
Control variable	Omit											

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Firstly, the grouping situations of OECD member countries are analyzed, as shown in Table 8. In the short-term, OECD member countries with smaller scale of environmental taxes revenues have better emission reduction effects, showing a significant short-term negative correlation between environmental taxes and greenhouse gas, sulfur oxide, and nitrogen oxide emissions. Taking greenhouse gas as an example, in the short term, the environmental taxes in countries with smaller tax scales increased by 1%, while the greenhouse gas emissions decreased significantly by 0.055% in the current period and 0.063% in the delayed period. OECD countries with larger environmental tax scales show a negative correlation with the emission of four kinds of gas pollutants, but the effect of emission reduction needs to be further strengthened. In the long run, countries with larger environmental tax scales have a certain degree of emission reduction effect on greenhouse gas and carbon dioxide emissions, while countries with smaller tax scales have not yet shown a significant long-term emission reduction effect.

Next, the grouping situations of Chinese provinces are analyzed, as shown in Table 9. In the short-term, the quasi-environmental tax emission reduction effect of Chinese provinces with smaller and medium-level environmental tax scales is also superior to that of provinces with larger scale taxes. This shows that the emission reduction effect of sulfur dioxide, ammonia nitrogen emission, and chemical oxygen demand in wastewater is the most obvious. Taking chemical oxygen demand for example, in provinces with smaller tax revenues, the 1% increase of the environmental tax in the first lag period leads to a 0.091% decline in the current chemical oxygen demand and a 0.108% significant decline in the first lag period, while the 1% increase of the environmental tax in the third lag period respectively leads to a 0.270% decline in the current chemical oxygen demand and a 0.264% significant decline in the first lag period. However, in the long run, China's provincial quasi-environmental tax has no obvious emission reduction effect on the "three wastes" under different tax scale groupings.

Based on the above analysis, it is found that OECD member countries and China's inland administrative provinces with small or medium environmental tax scales have significant short-term emission reduction effects, while the long-term emission reduction effect needs to be further strengthened. This paper speculates that this phenomenon mainly comes from the short-term "deterrent effect" of environmental taxes, that is, as long as the environmental tax is levied, regardless of its size, it can effectively affect the emission behavior of individuals and enterprises in the short term. However, with the passage of time and the expansion of collection scales, the effect of environmental taxes on emission reduction will be weakened. This grouping regression results provide empirical data for levying environmental taxes, improving the environmental tax system, and strengthening the effective and long-term implementation of environmental taxes.

4.4.2. Industrial Added Value

The foggy events in London, the four major public nuisances in Japan, the smog in the Beijing-Tianjin-Hebei region, the air pollution in Shanxi, China, the global economic development show that environmental pollution problems are accompanied by economic development. As the pillar of the national economy in the process of national industrialization, the secondary industry needs to consume a large amount of oil, coal, and natural gas resources in its development process, which will inevitably produce various environmental pollutants. Therefore, it is of great practical significance to investigate the emission reduction effects of environmental taxes in countries or provinces with different levels of industrial added value. Tables 10 and 11, respectively, show the emission reduction effects of environmental taxes in OECD countries and Chinese provinces under different levels of industrial added value.

Table 10. ARDL regression results of environmental tax emission reduction effects in OECD member countries with different industrial added value.

Variable	**GHE_OC**						**CO_2_OC**					
	Low		**Medium**		**High**		**Low**		**Medium**		**High**	
	Original	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**
LAG	−0.022 ** (0.031)	−1.040 *** (0.000)	0.007 (0.644)	−1.008 *** (0.000)	−0.028 *** (0.004)	−1.023 *** (0.000)	−0.077 *** (0.000)	−1.011 *** (0.000)	−0.012 (0.465)	−1.002 *** (0.000)	−0.042 *** (0.001)	−1.017 *** (0.000)
D_ET_OC	0.176 (0.203)	0.194 (0.173)	−0.097 (0.553)	−0.122 (0.466)	−0.031 (0.770)	0.021 (0.850)	0.201 (0.274)	0.283 (0.173)	−0.209 (0.275)	−0.239 (0.223)	−0.088 (0.476)	−0.039 (0.767)
L1_ET_OC	−0.050 *** (0.006)	−0.039 ** (0.029)	−0.043 (0.254)	−0.034 (0.357)	−0.028 (0.227)	−0.025 (0.321)	−0.017 (0.471)	−0.004 (0.882)	−0.026 (0.565)	−0.033 (0.454)	−0.030 (0.271)	−0.028 (0.352)
Control variable	Omit											
Variable	**SO_OC**						**NO_OC**					
	Low		**Medium**		**High**		**Low**		**Medium**		**High**	
	Original	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**
LAG	−0.043 *** (0.002)	−0.923 *** (0.000)	0.004 (0.590)	−0.896 *** (0.000)	−0.028 (0.142)	−0.838 *** (0.000)	−0.009 (0.397)	−0.976 *** (0.000)	0.013 ** (0.034)	−0.929 *** (0.000)	−0.033 *** (0.010)	−0.837 *** (0.000)
D_ET_OC	−0.358 (0.513)	−0.294 (0.602)	0.679 (0.327)	0.720 (0.310)	0.969 (0.309)	0.817 (0.411)	0.251 (0.186)	0.279 (0.156)	0.035 (0.870)	0.058 (0.794)	0.199 (0.468)	0.133 (0.633)
L1_ET_OC	−0.389 *** (0.000)	−0.139* (0.051)	−0.061 (0.721)	−0.094 (0.552)	−0.113 (0.640)	0.102 (0.591)	−0.104 *** (0.000)	−0.095 *** (0.000)	−0.089 * (0.059)	−0.064 (0.198)	−0.002 (0.966)	0.038 (0.472)
Control variable	Omit											

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Table 11. ARDL regression results of environmental tax emission reduction effects in Chinese inland provinces with different industrial added value.

Variable	**SO_2_CN**						**SW_CN**					
	Low		**Medium**		**High**		**Low**		**Medium**		**High**	
	Original	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**
LAG	−0.036 (0.537)	−0.898 *** (0.000)	−0.091 * (0.100)	−0.761 *** (0.000)	−0.154 (0.110)	−0.801 *** (0.001)	−0.041 (0.233)	−1.243 *** (0.000)	−0.040 (0.185)	−1.325 *** (0.000)	−0.028 (0.335)	−1.060 *** (0.000)
D_ET_CN	0.229 (0.347)	0.293 (0.268)	−0.032 (0.905)	0.235 (0.359)	0.720* (0.075)	1.068 *** (0.008)	0.112 (0.479)	0.149 (0.363)	−0.291 (0.202)	−0.305 (0.187)	0.293 (0.428)	0.305 (0.428)
L1_ET_CN	−0.062 (0.319)	−0.035 (0.597)	−0.298 *** (0.003)	−0.152 (0.107)	−0.424 *** (0.003)	−0.255 ** (0.047)	0.002 (0.944)	0.003 (0.936)	−0.096 (0.239)	−0.156 * (0.057)	−0.064 (0.473)	−0.040 (0.667)
Control variable	Omit											
Variable	**AN_CN**						**COD_CN**					
	Low		**Medium**		**High**		**Low**		**Medium**		**High**	
	Original	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**	**Original**	**The First Lag**
LAG	−0.152 ** (0.011)	−1.197 *** (0.000)	−0.416 *** (0.000)	−1.236 *** (0.000)	−0.332 *** (0.001)	−1.099 *** (0.000)	−0.118 ** (0.015)	−1.111 *** (0.000)	−0.228 ** (0.032)	−1.390 *** (0.000)	−0.323 *** (0.000)	−1.145 *** (0.000)
D_CET	0.003 *** (0.003)	0.003 *** (0.002)	0.001 (0.385)	0.001 (0.399)	0.004 *** (0.006)	0.005 *** (0.003)	0.019 ** (0.024)	0.021 ** (0.018)	0.007 (0.714)	0.024 (0.209)	0.052 *** (0.010)	0.042 ** (0.045)
L1_ET_CN	−0.001 (0.171)	−0.001 (0.429)	0.001 (0.357)	0.001 (0.706)	−0.001 (0.581)	0.000 (0.884)	−0.026 *** (0.008)	−0.024 ** (0.020)	0.006 (0.759)	0.000 (0.998)	−0.048 ** (0.043)	−0.053 ** (0.034)
L2_ET_CN	0.005 *** (0.001)	0.005 *** (0.006)	0.006 ** (0.025)	0.005* (0.076)	0.008 ** (0.015)	0.005 *** (0.152)	0.069 *** (0.000)	0.068 *** (0.000)	0.110 *** (0.003)	0.109 *** (0.002)	0.148 *** (0.001)	0.132 *** (0.003)
L3_ET_CN	−0.004 *** (0.000)	−0.004 *** (0.001)	−0.007 *** (0.001)	−0.006 *** (0.009)	−0.007 *** (0.002)	−0.005 ** (0.037)	−0.044 *** (0.000)	−0.045 *** (0.000)	−0.118 *** (0.000)	−0.113 *** (0.000)	−0.101 *** (0.001)	−0.081 *** (0.009)
Control variable	Omit											

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Firstly, the grouping situations of OECD countries are analyzed, as shown in Table 10. In the short term, the emission reduction effect of environmental taxes in OECD member countries with lower industrial added value is more significant, which is negatively correlated with the emissions of four types of gas pollutants. Taking greenhouse gas as an example, the 1% increase in environmental taxes in countries with lower industrial added value brings a significant decrease of 0.050% and 0.039% of greenhouse gas emissions in the current period and the lag period, respectively. However, the environmental taxes in the middle and high industrial added value group plays a role in curbing greenhouse gas emissions to some extent, but the short-term emission reduction effect is not significant. In the long run, environmental taxes in OECD countries with low industrial added value have certain inhibitory effects on sulfur oxides, while those in countries with medium and high industrial added value have certain inhibitory effects on greenhouse gases and carbon dioxide, but the effect is not significant.

We then analyze the grouping situation of the provinces in China, as shown in Table 11. In the short term, the environmental tax reduction effect on sulfur dioxide and industrial solid waste production in provinces with medium and high industrial added value is better than that in provinces with low industrial added value, while the reduction effect of environmental taxes on ammonia nitrogen emission and chemical oxygen demand of wastewater in provinces with low and high industrial added value is better than that in provinces with medium industrial added value. Taking sulfur dioxide emissions for example, the short-term regression coefficients between the environmental taxes of provinces with high industrial added value and the original as well as the lag phase sequences for sulfur dioxide are -0.424 and -0.255, respectively, which are significant at the confidence levels of 1% and 5%. That is to say, when the environmental tax rises by 1%, the sulfur dioxide emissions in the current period will be significantly reduced by 0.424%, and the lag phase will be significantly reduced by 0.255%. In addition, the environmental taxes for provinces with low industrial added value are beneficial in reducing sulfur dioxide emission in the short term but not conducive to reducing industrial solid waste emission. Taking the chemical oxygen demand in wastewater as an example, the first as well as the third lag periods for the environmental taxes in provinces with low and high industrial added value have significant emission reduction effects on the chemical oxygen demand in the current period and the first lag period, while the environmental taxes of the provinces with medium levels of industrial added value only shows significant emission reduction effects on the third lag period. In the long run, the environmental taxes of provinces with medium industrial added value have a certain inhibitory effect on sulfur dioxide and industrial solid waste, but the effect is not significant.

Based on the above analysis, the results of the six sets of experiments under the industrial value added group show that on the one hand, the long-term emission reduction effects of environmental taxes need to be further strengthened, which is the same problem faced by OECD member countries and Chinese provinces. On the other hand, OECD countries with low industrial added value have a relatively good effect on emission reduction via environmental taxes, while China shows that the provinces with high industrial added value have a better effect on emission reduction via environmental taxes, which is the biggest difference between them under the grouping of industrial added value. This paper speculates that the different industrialization processes for the two is the important reason for different emission reduction effects under different grouping conditions. The OECD started industrialization process early, at present, most OECD countries, such as Britain, France, the United States, and other western countries, have already completed the industrialization process, therefore the secondary industry is no longer the main economic growth point. In addition, these countries with low industrial added value have achieved good environmental performance due to their early use of economic and legal means to regulate environmental pollution in the process of economic development. China's industrialization process is relatively late, but fully draws on the experience of western developed countries. In recent years, China has actively advocated for adjusting and optimizing the industrial structure, while advocating for the transformation of the mode of economic development. China's high-industrial value-added provinces, such as Jiangsu, Zhejiang, Shandong, and other coastal economically developed regions, fully rely on the advantages of science and technology, capital, and talent in the process of industrialization, and actively promote industrial upgrades, research, and development into environmental protection technologies, thereby achieving high efficiency and green and low-carbon development.

4.4.3. Level of Economic Development

On the one hand, the economic foundation determines the superstructure. Environmental pollution control is a long-term effort with a huge demand for funds, which requires strong financial and material support from the state. On the other hand, environmental pollution usually gets enough attention from society when the economy is highly developed, because when the population's material life is satisfied, people will have more time and energy to invest in environmental governance, and the awareness of environmental protection will continue to improve with the process of economic development. Therefore, the discussion on the effects of environmental taxes on emission reduction at different levels of economic development can provide a useful reference for coordinating national and regional economic development to cope with environmental governance issues, and for implementing environmental protection policies according to regional development status. Tables 12 and 13, respectively, show the emission reduction effects of environmental taxes in OECD countries and Chinese provinces at different levels of economic development.

Table 12. ARDL regression results of environmental tax emission reduction effects in OECD member countries with different levels of economic development.

Variable	GHE_OC				CO_2_OC			
	Low		High		Low		High	
	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag
LAG	−0.050 *** (0.001)	−1.044 *** (0.000)	−0.013 ** (0.022)	−1.001 *** (0.000)	−0.066 *** (0.000)	−1.024 *** (0.000)	−0.028 *** (0.002)	−1.002 *** (0.000)
D_ET_OC	0.271 ** (0.014)	0.217 * (0.059)	−0.217 ** (0.045)	−0.185 * (0.091)	0.348 ** (0.012)	0.311 ** (0.042)	−0.352 *** (0.005)	−0.323 ** (0.012)
L1_ET_OC	0.013 (0.515)	−0.024 (0.173)	−0.040 (0.114)	−0.023 (0.353)	0.025 (0.246)	−0.003 (0.912)	−0.044 (0.121)	−0.032 (0.272)
Control variable	Omit							
Variable	SO_OC				NO_OC			
	Low		High		Low		High	
	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag
LAG	−0.027 *** (0.003)	−0.823 *** (0.000)	0.013 (0.179)	−0.863 *** (0.000)	−0.005 (0.332)	−1.003 *** (0.000)	−0.007 (0.353)	−0.830 *** (0.000)
D_ET_OC	0.473 (0.409)	0.539 (0.361)	−0.220 (0.721)	−0.282 (0.649)	0.278 ** (0.036)	0.264 * (0.055)	−0.142 (0.534)	−0.158 (0.473)
L1_ET_OC	−0.150 (0.127)	0.009 (0.922)	−0.067 (0.665)	−0.183 (0.154)	−0.047 ** (0.023)	−0.051 ** (0.017)	−0.093* (0.072)	−0.030 (0.510)
Control variable	Omit							

Note: p-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Table 13. ARDL regression results of environmental tax emission reduction effects in Chinese provinces with different levels of economic development.

Variable	SO_2_CN						SW_CN					
	Low		Medium		High		Low		Medium		High	
	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag
LAG	−0.131 * (0.076)	−1.030 *** (0.000)	−0.055 (0.247)	−0.849 *** (0.000)	−0.103 (0.275)	−0.889 ** (0.012)	−0.004 (0.841)	−1.084 *** (0.000)	−0.029 (0.350)	−1.202 *** (0.000)	−0.110* (0.061)	−1.196 *** (0.000)
D_ET_CN	0.021 (0.925)	0.089 (0.708)	0.150 (0.605)	0.436 (0.129)	0.725* (0.058)	0.969 ** (0.016)	0.126 (0.384)	0.082 (0.583)	−0.047 (0.879)	−0.020 (0.951)	−0.121 (0.550)	-0.110 (0.566)
L1_ET_CN	−0.117 ** (0.025)	−0.071 (0.176)	−0.122 (0.147)	−0.079 (0.359)	−0.399 ** (0.019)	−0.278 (0.136)	−0.032 (0.258)	−0.034 (0.247)	−0.025 (0.795)	−0.046 (0.646)	−0.127 (0.113)	−0.206 *** (0.006)
Control variable	Omit											

Variable	AN_CN						COD_CN					
	Low		Medium		High		Low		Medium		High	
	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag	Original	The First Lag
LAG	−0.291 *** (0.000)	−1.334 *** (0.000)	−0.255 *** (0.000)	−1.155 *** (0.000)	−0.210 ** (0.034)	−0.976 *** (0.000)	−0.158 ** (0.018)	−1.267 *** (0.000)	−0.248 *** (0.000)	−1.184 *** (0.000)	−0.285 ** (0.020)	−1.261 *** (0.000)
D_ET_CN	0.0005 (0.649)	0.001 (0.342)	0.004 *** (0.002)	0.004 *** (0.002)	0.004 *** (0.004)	0.004 *** (0.008)	0.005 (0.760)	0.014 (0.381)	0.035 *** (0.003)	0.036 *** (0.004)	0.039 * (0.091)	0.036 (0.134)
L1_ET_CN	0.001 (0.393)	0.001 (0.217)	−0.002 (0.189)	−0.002 (0.195)	0.002 (0.320)	0.001 (0.511)	−0.009 (0.633)	−0.007 (0.715)	−0.019 (0.150)	−0.018 (0.229)	−0.008 (0.743)	−0.018 (0.465)
L2_ET_CN	0.003 * (0.083)	0.003 (0.181)	0.010 *** (0.000)	0.009 *** (0.001)	0.003 (0.223)	0.002 (0.448)	0.076 ** (0.016)	0.071 ** (0.024)	0.091 *** (0.000)	0.084 *** (0.001)	0.085 ** (0.033)	0.084 ** (0.042)
L3_ET_CN	−0.005 *** (0.000)	−0.00 5*** (0.000)	−0.007 *** (0.000)	−0.007 *** (0.000)	−0.004 ** (0.035)	−0.003 (0.167)	−0.073 *** (0.001)	−0.071 *** (0.001)	−0.072 *** (0.000)	−0.071 *** (0.000)	−0.071 ** (0.028)	−0.055 * (0.082)
Control variable	Omit											

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Firstly, the grouping situation of OECD countries is analyzed, as shown in Table 12. In the short run, countries with GDP growth rates higher than 2.5% have better environmental tax emission reduction effects than those with low growth rates. Except for nitrogen oxides, the environmental taxes of OECD countries whose GDP growth rate is higher than 2.5% have a short-term negative correlation with greenhouse gas, carbon dioxide, and sulfur oxide emissions, while the environmental tax reduction effects of countries whose GDP growth rate is lower than 2.5% is not obvious. In the long run, environmental taxes in countries with GDP growth above 2.5% significantly reduce most of the gas pollutants. Taking carbon dioxide as an example, in OECD member countries with GDP growth rates higher than 2.5%, the regression coefficients between environmental taxes and the original as well as the first lag period of carbon dioxide are -0.352 and -0.323, respectively, both of which are significant at the confidence levels of 1% and 5%; that is, the 1% increase in environmental taxes brings a significant decrease of 0.352% of CO2 in the current period and 0.352% of CO_2 in the first lag period.

Next, the grouping situation of Chinese provinces is analyzed, as shown in Table 13. In the short term, the environmental tax emission reduction effect in provinces with medium and high speed economic growth is generally better. Taking pollutants in provinces with high levels of economic growth as an example, the environmental taxes under this group significantly reduces sulfur dioxide emissions and industrial solid waste production in the current period, and shows a significant negative correlation with ammonia nitrogen emissions and chemical oxygen demand in wastewater. In the long run, the environmental taxes of the provinces with medium and high speeds of economic growth can reduce the emission of industrial solid waste to some extent.

Based on the above analysis, the results of OECD and Chinese grouping experiments in this case show that the higher the level and speed of economic development, the more effective the environmental taxes will be in reducing emissions, indirectly proving that environmental governance needs strong support from national and local finance. The ecological environment will be continuously optimized with the development of a high-level and high-quality green economy.

5. Robustness Test

To validate the above results, this paper changes the regression method used, that is, the Generalized Linear Model (GLM) which was introduced by Nelder et al. [55] in 1972 is applied to regress the variables in Equations (1) and (2), as shown below.

$$\begin{aligned} \Delta LogGHE\_OC &= \alpha_0 + \alpha_1 ET\_OC + \alpha_2 LogOP\_OC + \alpha_3 OIL\_OC \\ &\quad + \alpha_4 CA\_OC + \alpha_5 GDP\_OC + \alpha_6 IND\_OC \end{aligned} \tag{3}$$

$$\begin{aligned} \Delta LogSO_2\_CN &= \alpha_0 + \alpha_1 ET\_CN + \alpha_2 LogOP\_CN + \alpha_3 OIL\_CN \\ &\quad + \alpha_4 CA\_CN + \alpha_5 GDP\_CN + \alpha_6 IND\_CN \end{aligned} \tag{4}$$

In order to stay consistent with Equations (1) and (2), the dependent variables GHE_OC and SO_OC in Equations (3) and (4) were treated by differences, respectively. To simplify the space, the GHE_OC in Equation (3) was successively replaced by CO_2_OC, SO_OC and NO_OC on the premise that the independent variable ET_OC and the control variables OP_OC, OIL_OC, CA_OC, GDP_OC, and IND_OC remained unchanged. Then, the model to test the effect of OECD environmental tax on reducing pollutants was obtained. Similarly, under the premise of keeping the independent variable ET_CN unchanged and the control variables OP_CN, OIL_CN, CA_CN, GDP_CN, and IND_CN partly unchanged, the SO_2_CN in Equation (4) is replaced by SW_CN, AN_CN, and COD_CN in turn, and the model for testing the effect of environmental tax on pollutant reduction in China can be obtained. Considering the consistency with Equation (2), in the equation with AN_CN and COD_CN as dependent variables, ET_CN was added with a lag of one, two, and three periods. In Equations (3) and (4), α_0 is a constant term, α_1 is the regression coefficient of independent variable ET_OC and dependent variable GHE_OC in Equation (3), and independent variable ET_CN and dependent variable SO_2_CN in Equation (4), respectively. Here, α_2 to α_6 are regression coefficients of ET_OC, ET_CN, and control variables, respectively.

The results of Generalized Linear Model (GLM) validate the above regression results based on panel ARDL, which was as shown from Tables 14–18. The results obtained by the two methods show great consistency.

Table 14. Generalized Linear Model regression results of environmental tax pollutant reduction effects in OECD countries.

Variables	GHE_OC		CO_2_OC		SO_OC		NO_OC	
ET_OC	−0.0416 **	□	−0.0290	□	−0.0917	□	−0.0644 ***	□
	(0.0303)	□	(0.2056)	□	(0.1951)	□	(0.0063)	□
L1_ET_OC	□	−0.0480 **	□	−0.0359	□	-0.0948	□	−0.0782 ***
	□	(0.0123)	□	(0.1162)	□	(0.1810)	□	(0.0009)
OP_OC	0.0026 **	0.0024 **	0.0046 ***	0.0043 ***	0.0021	0.0018	0.0007	0.0004
	(0.0150)	(0.0245)	(0.0004)	(0.0008)	(0.5846)	(0.6391)	(0.5910)	(0.7400)
OIL_OC	0.0027 ***	0.0028 ***	0.0025 **	0.0026 **	0.0067 **	0.0066 **	0.0023 **	0.0026 **
	(0.0016)	(0.0010)	(0.0147)	(0.0106)	(0.0301)	(0.0333)	(0.0229)	(0.0120)
CA_OC	−0.0016	−0.0017	−0.0017	−0.0018	0.0035	0.0033	−0.0013	−0.0014
	(0.1373)	(0.1056)	(0.1852)	(0.1498)	(0.3641)	(0.3931)	(0.3348)	(0.2714)
GDP_OC	0.2303 ***	0.2256 ***	0.2728 ***	0.2680 ***	0.2314 ***	0.2207 ***	0.2365 ***	0.2306 ***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0031)	(0.0051)	(0.0000)	(0.0000)
IND_OC	0.0282 **	0.0290 **	0.0188	0.0196	0.0216	0.0211	0.0316 **	0.0301 *
	(0.0323)	(0.0262)	(0.2331)	(0.2075)	(0.6556)	(0.6615)	(0.0499)	(0.0607)
_cons	−0.0233 ***	−0.0224 ***	−0.0273 ***	−0.0262 ***	−0.0577 ***	−0.0557 **	−0.0248 ***	−0.0226 ***
	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0090)	(0.0115)	(0.0007)	(0.0020)

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Table 15. GLM regression results of environmental tax pollutant reduction effects in Chinese provinces.

Variables	SO_2_CN		SW_CN		AN_CN		COD_CN	
ET_CN	−0.1396 ***	□	−0.0523 **	□	0.0002	0.0028 ***	0.0017	0.0252 ***
	(0.0000)	□	(0.0372)	□	(0.1273)	(0.0000)	(0.2725)	(0.0038)
L1_ET_CN	□	−0.1728 ***	□	−0.0598 **	□	−0.0042 ***	□	−0.0534 ***
	□	(0.0000)	□	(0.0269)	□	(0.0003)	□	(0.0004)
L2_ET_CN	□	□	□	□	□	0.0067 ***	□	0.1049 ***
	□	□	□	□	□	(0.0000)	□	(0.0000)
L3_ET_CN	□	□	□	□	□	−0.0060 ***	□	−0.0850 ***
	□	□	□	□	□	(0.0000)	□	(0.0000)
OP_CN	−0.0346 **	−0.0334 **	−0.0364 ***	−0.0361 ***	-0.00002	0.00001	-0.0005	0.0001
	(0.0190)	(0.0219)	(0.0034)	(0.0035)	(0.6996)	(0.8020)	(0.4720)	(0.9014)
OIL_CN	0.0196	0.0214 *	□	□	□	□	□	□
	(0.1304)	(0.0926)	□	□	□	□	□	□
CA_CN	−0.0018	−0.0018	0.0006	0.0006	□	□	□	□
	(0.3388)	(0.3485)	(0.6744)	(0.6806)	□	□	□	□
GDP_CN	0.2567 ***	0.2325 ***	0.3957 ***	0.3902 ***	0.0024 ***	0.0019 ***	0.0295 ***	0.0258 ***
	(0.0003)	(0.0009)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
IND_CN	0.1231 *	0.1083*	0.1333 **	0.1308 **	0.0004 *	0.0003	0.0066 **	0.0044
	(0.0605)	(0.0953)	(0.0154)	(0.0174)	(0.0978)	(0.2966)	(0.0382)	(0.2006)
_cons	0.0268	0.0343	0.0507	0.0516	−0.0005 **	−0.0005 **	−0.0061 **	−0.0069 ***
	(0.6320)	(0.5352)	(0.2804)	(0.2690)	(0.0123)	(0.0121)	(0.0115)	(0.0092)

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Table 16. GLM regression results of environmental tax emission reduction effects in OECD countries and Chinese provinces with different levy scales.

OECD	**GHE_OC**		**CO_2_OC**		**SO_OC**		**NO_OC**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
ET_OC	−0.0606 * (0.0637)	−0.0868 ** (0.0300)	0.0126 (0.7473)	−0.1099 ** (0.0199)	−0.1568 (0.2161)	−0.0606 (0.6721)	−0.0913 * (0.0595)	−0.0370 (0.3674)
Control Variables	Omit							

China	**SO_2_CN**			**SW_CN**			**AN_CN**			**COD_CN**		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
ET_CN	−0.6952 *** (0.0010)	−0.2892 *** (0.0000)	−0.0881 ** (0.0438)	−0.1063 (0.3619)	−0.0882 (0.1295)	−0.0449 (0.1168)	0.0076 *** (0.0055)	0.0019 * (0.0872)	0.0034 *** (0.0004)	0.0583 (0.1043)	0.0127 (0.3939)	0.0328 *** (0.0020)
L1_ET_CN							−0.0059 (0.1790)	−0.0022 (0.2202)	−0.0059 *** (0.0006)	−0.1623 *** (0.0046)	−0.0158 (0.4954)	−0.0690 *** (0.0003)
L2_ET_CN							0.0095 (0.1453)	0.0053 *** (0.0078)	0.0076 *** (0.0000)	0.3258 *** (0.0001)	0.0946 *** (0.0003)	0.0960 *** (0.0000)
L3_ET_CN							−0.0157 *** (0.0020)	−0.0055 *** (0.0002)	−0.0055 *** (0.0000)	−0.2668 *** (0.0001)	−0.0981 *** (0.0000)	−0.0639 *** (0.0000)
Control Variables	Omit											

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Table 17. GLM regression results of environmental tax emission reduction effects in OECD countries and Chinese provinces with different industrial added value.

OECD	GHE_OC			CO_2_OC			SO_OC			NO_OC		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
ET_OC	−0.0643 ** (0.0302)	0.0290 (0.5748)	−0.0731 * (0.0638)	−0.0410 (0.2688)	0.0298 (0.6156)	−0.0887 * (0.0584)	−0.2309 *** (0.0097)	0.0730 (0.6496)	0.1381 (0.4492)	−0.1184 *** (0.0002)	−0.0387 (0.4578)	−0.0351 (0.5390)
Control Variables	Omit											
China	**SO_2_CN**			**SW_CN**			**AN_CN**			**COD_CN**		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
ET_CN	−0.0686 (0.1498)	−0.3049 *** (0.0002)	−0.3437 *** (0.0028)	−0.0272 (0.3406)	−0.1529 ** (0.0231)	−0.0533 (0.4653)	0.0033 *** (0.0001)	0.0009 (0.5810)	0.0047 *** (0.0015)	0.0264 *** (0.0021)	0.0032 (0.8719)	0.0445 ** (0.0289)
L1_ET_CN							−0.0059 *** (0.0001)	-0.0014 (0.5669)	−0.0053 ** (0.0296)	−0.0624 *** (0.0000)	−0.0121 (0.6985)	−0.1019 *** (0.0023)
L2_ET_CN							0.0074 *** (0.0000)	0.0066 ** (0.0217)	0.0042 (0.1770)	0.0905 *** (0.0000)	0.1188 *** (0.0011)	0.1287 *** (0.0024)
L3_ET_CN							−0.0053 *** (0.0000)	−0.0068 *** (0.0015)	−0.0042 * (0.0509)	−0.0583 *** (0.0000)	−0.1230 *** (0.0000)	−0.0770 *** (0.0095)
Control Variables	Omit											

Note: *p*-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

Table 18. GLM regression results of environmental tax emission reduction effects in OECD countries and Chinese provinces with different levels of economic development.

OECD	**GHE_OC**		**CO_2_OC**		**SO_OC**		**NO_OC**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
ET_OC	−0.0548 ** (0.0488)	−0.0392 (0.2884)	−0.0350 (0.3069)	−0.0509 (0.2346)	−0.0597 (0.5410)	−0.1102 (0.4188)	−0.0715 *** (0.0048)	−0.0615 (0.2379)
Control Variables	Omit							

China	**SO_2_CN**			**SW_CN**			**AN_CN**			**COD_CN**		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
ET_CN	−0.0981 *** (0.0096)	−0.1621 ** (0.0330)	−0.3605 ** (0.0171)	−0.0203 (0.3925)	−0.0684 (0.4023)	−0.1611 *** (0.0050)	0.0014 (0.1787)	0.0050 *** (0.0001)	0.0037 *** (0.0078)	0.0152 (0.3556)	0.0434 *** (0.0004)	0.0230 (0.3137)
L1_ET_CN							−0.0022 (0.2568)	−0.0079 *** (0.0004)	−0.0032 * (0.0908)	−0.0450 (0.1379)	−0.0686 *** (0.0010)	−0.0552 * (0.0749)
L2_ET_CN							0.0060 *** (0.0027)	0.0108 *** (0.0000)	0.0022 (0.3468)	0.1164 *** (0.0002)	0.1002 *** (0.0000)	0.0879 ** (0.0230)
L3_ET_CN							−0.0059 *** (0.0000)	−0.0084 *** (0.0000)	−0.0032 * (0.0823)	−0.0953 *** (0.0000)	−0.0834 *** (0.0000)	−0.0595 ** (0.0447)
Control Variables	Omit											

Note: p-values are reported in parentheses below coefficient estimates. Significance levels of 0.1, 0.05, and 0.01 are denoted by *, **, and ***, respectively.

6. Conclusions

6.1. Research Conclusion

Based on the "green dividend" theory of environmental taxes, this paper compares and analyzes the emission reduction effects of environmental taxes in 35 OECD countries and 31 inland provinces of China. Through the establishment of the panel ARDL model, the empirical tests found that on the whole, environmental tax policy helps to reduce pollutant emissions to a large extent, both in OECD countries and Chinese countries. Further analysis shows that, firstly, the environmental taxes have significant short-term emission reduction effects in both OECD member countries and Chinese administrative provinces with small or medium scales of environmental tax collection, while the long-term emission reduction effect needs to be further strengthened. This proves that the scale of environmental tax collection is not the decisive factor affecting the effect of environmental tax on reducing pollutants, which provides empirical data for countries and regions with serious environmental pollution wanting to levy an environmental tax. Secondly, the short-term emission reduction effects of environmental taxes in OECD countries with low industrial added value are relatively good, while in China, the emission reduction effects are better in provinces with high industrial added value. This shows that environmental taxes should be promoted in an orderly manner in the process of national industrialization. Thirdly, the environmental taxes of OECD countries and Chinese provinces with high economic growth levels have good short-term emission reduction effects, and the environmental taxes of OECD countries with high economic growth levels significantly reduce greenhouse gas and sulfur dioxide emissions in the long term. This shows that reducing pollution requires sufficient capital, while attaching importance to economic development as well as levying environmental taxes can provide financial support for environmental protection.

6.2. Research Enlightement

The implications of this article are as follows. Firstly, environmental taxes help to reduce pollutant emissions. Therefore, countries facing environmental pollution problems can realize the balance of economic development and environmental sustainability by levying environmental taxes.

Secondly, the characteristics of pollution costs internalized by environmental tax and the mechanisms of exemption and credit via environmental taxes can promote the adjustment of industrial structures and economic development modes. Environmental taxes can be used as an effective means to reduce pollutants in the process of industrialization.

Thirdly, emission reduction of pollutants requires sufficient economic resources. Government authorities can raise funds for environmental protection by introducing environmental taxes in the process of economic development.

The limitations and follow-up studies of this paper focus on the following aspects: there was no specific study on the pollutant emission reduction effects of specific OECD and Chinese environmental taxes (e.g., energy taxes, vehicle traffic taxes); the intermediary role of green investment and technological innovation in environmental tax pollutant emission reduction was not considered; further consideration should be given to the emission reduction effects of environmental taxes under different grouping conditions (e.g., the level of green investment and the intensity of environmental supervision).

Author Contributions: P.H. and Z.Y. conceived and designed the research method used in this paper; H.S. and H.X. collected the data used for empirical analysis; J.N. and H.J. performed the empirical analysis and wrote the paper.

Funding: This research was funded by the National Social Science Fund of China (17BGL051).

Acknowledgments: This research was supported by the National Social Science Fund of China (17BGL051).

Conflicts of Interest: The authors declare no conflicts of interest.

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