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# Determining Whether Trade Can Affect Regional Environmental Sustainability from the Perspective of Environmental Pollution

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**Abstract:** The rising level of environmental pollution in China indicates that the current pattern of economic development is unsustainable. Therefore, ensuring environmental quality places higher requirements on China's economic development pattern from the perspective of sustainability. At the same time, the rapid growth of China's total trade is an important driving force for China's rapid economic development. Based on the trade and environmental quality data of China's 30 provincial administrative divisions, this paper uses a Dynamic Spatial Durbin Model to analyze the environmental quality effects of trade—that is, the composition, technical, and scale effect. Moreover, the environmental quality effects of trade are compared and analyzed in different regions. In this paper, the wastewater discharge and sulfur dioxide discharge are selected as the indicators of environmental pollution. The results show that the scale effect of trade is significantly negative, and that the scale effect is greater than the composition effect. Trade development is conducive to reducing regional environmental pollution. The main impact of trade development on reducing environmental pollution is through economies of scale. The composition effect and technology effect are smaller than the scale effect. The increase in trade in services has helped to reduce the growth rate of pollution emissions. Therefore, expanding service trade and optimizing the trade structure will help to reduce the intensity of pollutive emissions and thereby improve the sustainability of regional economic development.

**Keywords:** trade in goods; trade in services; environmental pollution; scale effect; technical effect; composition effect

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## 1. Introduction

Is trade development one of the ways to achieve sustainable development? From the perspective of environmental pollution, the process of trade can reduce environmental pollution when trade growth and environmental pollution are related. Therefore, trade is one of the approaches to promote sustainable development. For a long time, the correlation between trade and environmental pollution has been the research focus for many scholars. A correlation has been shown between an increase in the trade volume and an increase in the degree of environmental pollution in the economic growth in various countries. Scholars believe that, in the process of economic development, per capita income and environmental pollution show an inverted U-shaped relationship: that is, an increase in per capita income will increase the degree of environmental pollution [1]. However, in the long run, when per capita income reaches a certain level, the continued growth of income will reduce the degree of environmental pollution. Therefore, trade can theoretically reduce environmental pollution by promoting income growth or technological progress. In reality, environmental pollution in developing countries represented by China has negatively affected the long-term economic growth and people's

health. Improving the ecological environment and controlling environmental pollution both have great urgency. The growth of trade is one of the most important characteristics of China's economic growth. China has a large amount of trade goods, ranking second among countries in the world in this regard. At the same time, the rapid growth of service trade is an important part of China's total international trade growth and an important manifestation of China's international trade structure adjustment. From 2002 to 2018, China's service trade has maintained a growth rate of 20%. From the perspective of the existing academic theory, the improvement of trade quality is one of the potential channels to explain the environmental effects of trade. Empirical research on the effect helps to explore theoretical analysis of trade affecting environmental pollution. From a practical point of view, the assumption that trade growth helps to reduce environmental pollution has realistic significance in policy, helping to control environmental pollution from a trade policy perspective, and achieving sustainable development of regional environment and economic growth. The research objectives of this article are to explore the correlation between environmental pollution and trade growth, and to explore whether the structure of trade growth has an impact on environmental pollution. Based on the background and mechanism of this effect, this article further analyzes the feasibility of a trade policy in controlling environmental pollution.

## 2. Literature Review

The sustainability of economic development is gradually being evaluated, and scholars have examined the relationship between trade and the environment. Wang (2019) pointed out that the development of international trade is an important manifestation of sustainable development, and that international trade is a source of power for the sustained growth of the global economy. Moreover, the proportion of traditional energy-intensive products in international trade has decreased, and the proportion of new energy in international trade has increased, which has optimized the international trade structure, and, therefore, has had a positive impact on the sustainability of ensuring a high level of environmental quality [2]. Grossman and Krueger (1993) argued that the causal relationship between trade and pollution is two-way [3]. Hu and Pan (2007) pointed out that the focus of environment and trade research is the feedback effect of international trade and the environment [4]. Savona and Ciarli (2019) examined composition changes and sustainability, pointing out that global trade trends and changes in emission intensities support the pollution paradise hypothesis that the intensity of environmental pollution has shifted from developed to emerging countries [5]. Tian and Liao (2009) pointed out that the focus of the debate on the impact of trade on environmental quality is that trade contributes to the improvement of the efficiency of global resource allocation, while trade may cause demand and production expansion at the cost of environmental damage [6]. Li et al. (2016) analyzed the theory of traditional comparative advantage and believed that the environmental quality depends on the comparative advantages of production costs and pollution discharge costs between the two countries. Trade is conducive to the optimization of global pollution emissions [7]. Grossman and Krueger (1991) decomposed the effects of international trade on the environment into three aspects: the scale effect, composition effect, and technical effect, thereby establishing a basic framework for the theoretical analysis of the environmental effects of international trade [8]. However, Copeland and Taylor (2013) also pointed out that environmental policies may be endogenous. Therefore, the differences in endogenous environmental policies in countries with different levels of development have led to the pollution paradise hypothesis [9].

Liu (2018) believed that the growth of service trade is an important performance of trade structure adjustment, and, therefore, an important channel for improving trade quality and environmental quality [10]. The service industries involved in service trade are generally considered to be clean industries and rarely produce polluted products, which is different from the pollution generation mechanism of the secondary industries. The service industry is a smoke-free industry and will not bring common pollutants, such as wastewater and waste gas, and is an environmentally friendly trade category [11]. Therefore, the trade structure is also an important channel affecting environmental

pollution. Alcántara and Padilla (2009), using an input-output system analysis, pointed out that transport services in service trade have a direct relationship with environmental pollution, and that service trade has a pulling effect on economic activities, so the impact of service trade on the environment should not be ignored [12]. Ying (2018) proposed that the service industry has characteristics, such as intangibility and knowledge spillover, so the service trade process has positive externalities to the regional environmental quality [13]. The knowledge spillover effect of service trade can promote production intensification. Dosi (1988) pointed out that the penetration of non-physical knowledge into agriculture and industry has improved the efficiency of resource utilization and can reduce resource consumption, achieve environmentally optimized production, and improve the sustainability of development [14]. In addition, the environmental influencing mechanism of trade in services is the knowledge innovation effect. Taking service trade and water environment quality as examples, the development of the international service trade helps promote economic growth, causes economic growth to rise, and promotes technological innovation that favors high-quality environments. Ni and Yu (2011) analyzed the environmental effects of US service trade exports and pointed out that service trade exports can reduce carbon monoxide, non-methane organic volatiles, and nitrogen oxide pollution emissions [15]. Lee et al. (2019) showed that the route optimization of urban express delivery services can reduce pollution emissions based on South Korean research, which verified the correlation between the service industry and pollution emissions [16].

The empirical research of the correlation between the rapid growth of trade and environmental pollution is another research focus. Li (2009) believed that Chinese scholars' concerns about international trade and environmental issues originate from the rapid growth of China's international trade and the intensification of environmental pollution [17]. Sun and Zang (2009) pointed out that China's data from 2002 to 2006 showed that, while China's exports increased, energy-intensive and environmental-pollution-intensive trends in export products exhibited an upward trend [18]. Li and Chen (2019) pointed out that the trade in services and the ecological environment are related based on the study of the coordination degree model of the composite system [19]. Peters and Hertwich (2006) pointed out that the carbon emissions in Norwegian imports represented 67% of domestic carbon emissions [20]. In the research framework, international investment and environmental regulations are considered to have the potential to affect the environmental effects of trade. In the process of empirical analysis, many factors were incorporated into the analysis framework of the environmental effects of trade, such as the strength of environmental regulations, foreign direct investment, and GDP [21–24]. From the perspective of empirical methods, the selection of environmental pollution indicators is heterogeneous with empirical results [25].

Research at the regional level indicates that the degree of regional development may also affect the environmental effects of trade. The effect of goods trade on the environment have been verified by Chinese regional data [26–31]. The effect may be affected by the resource or GDP of the region [32–34]. The regions with lower output values may loosen environmental regulations due to fiscal pressures, thereby exacerbating local environmental pollution while trade and environmental regulations have a positive effect on reducing environmental pollution [35]. Another possible explanation is that the level of corporate social responsibility (CSR) communication in economically underdeveloped areas is generally low. A low level of social responsibility communication will make the company less ethical, and thus relax the restrictions on pollution emissions [36–38].

In terms of empirical methods, the endogenous relationship between trade openness and the environment requires special attention. Dai et al. (2015) argued that theoretical and empirical studies did not form unity in terms of the relationship between environment and trade. The possible two-way causality between environment and trade is one of the explanations, and the endogenous relationship of the two must be incorporated into the framework of analysis [39].

Most of the studies on China's trade and environmental issues analyze the impact of international trade liberalization or trade development in terms of environmental quality from the perspective of trade in goods, rarely analyzing the relationship between international service trade and the

environment. To analyze the relationship between trade and environmental sustainability, this paper selects water environmental pollution as a measure of environmental pollution and sulfur dioxide emissions as a measure of the robustness test part to ensure the effectiveness of the study. At the same time, considering that the discharge of environmental pollutants will be affected by environmental governance, this paper sets control variables, such as environmental governance and international investment openness. The model addresses possible endogenous issues between trade structure and economic development by using appropriate substitution variables. Finally, this article examines the differences in the impact of trade on environmental pollution in different regions of China by grouping the samples after the verification of the basic model.

### 3. Model Building and Data Interpretation

#### 3.1. Model Building

According to the existing research results, the theoretical model proposed by Antweiler, Copeland, and Taylor (2001) is used as the main framework for empirical analysis, and the impact of international trade on the environment is divided into scale, technical, and composition effect [40]. The scale effect refers to changes in the environment due to changes in the scale of economic activities. The scale of economic activities is mainly measured by the use of per capita income. The technical effect mainly refers to the changes brought about by technological innovation. Here, trade openness is used as an index to measure technological innovation. Generally speaking, the lower the degree of trade liberalization, the lower the pollution emission intensity per unit output value. The composition effect mainly refers to the difference in the production structure caused by the difference in factor endowments, which is the product structure of clean products and polluting products. Therefore, scholars generally use the capital–labor ratio for measurement in their research. Based on existing theoretical assumptions, the econometric model is constructed as follows:

$$Z_{it} = \alpha + \beta_1 KL_{it} + \beta_2 B_{it} + \beta_3 I_{it} + \varepsilon_{it} \quad (1)$$

where  $i$  ( $i = 1, 2, 3, \dots, N$ ) represents different provinces in China. Additionally,  $t$  ( $t = 1, 2, 3, \dots, T$ ) represents the selected year.  $Z$ , which is the explanatory variable, represents the amount of pollutants discharged by each province. The environmental pollution situation is measured by the total amount of wastewater discharged by each province each year.  $\alpha$  is a constant term;  $\beta_1$ ,  $\beta_2$ , and  $\beta_3$  represent the composition effect, technical effect, and scale effect estimation parameters, respectively;  $\varepsilon$  represents the random error term of the model;  $KL$  represents the composition of factor endowment, measured by the ratio of the total investment to the number of employees at the end of the year, which reflects the differences in capital and labor factor endowments in each province;  $B$  represents trade openness, which is measured by the proportion of the total value of imports and exports of goods in the GDP;  $I$  represents the scale of economy, which is generally measured by per capita income. This article uses the per capita GDP as an indicator for scale.

Lesage and Pace (2009) comprehensively considered the spatial dependence of dependent variables and independent variables and constructed a Spatial Durbin Model (SDM), which includes the spatial lag of dependent variables and the spatial lag of independent variables [41]. Based on the advantages of the Spatial Panel Durbin Model, this paper establishes a spatial measurement model of China's international trade and environmental pollution. Environmental pollution in a region may be affected by a series of factors related to the region, or a series of factors in neighboring regions. These logical relationships can be illustrated by a Spatial Durbin Model, which can be written in Equation (2) in dynamic form:

$$Z_{it} = \alpha + \tau Z_{it-1} + \rho WZ_{it} + \eta WZ_{t-1} + \beta_1 KL_{it} + \beta_2 B_{it} + \beta_3 I_{it} + \beta_4 Gov_{it} + \beta_5 FDI_{it} + \beta_6 Service_{it} + \theta_1 WKL_{it} + \theta_2 WB_{it} + \theta_3 WI_{it} + \theta_4 WGov_{it} + \theta_5 WFDI_{it} + \theta_6 WService_{it} + \mu_{it} + \varepsilon_{it} \quad (2)$$

where  $Gov_{it}$  indicates the environmental governance of each province;  $FDI_{it}$  indicates the foreign capital openness of each province. The environmental regulations and international investment are considered to be control variables. At the same time, in order to examine whether service trade has a positive effect in theoretical analysis, this paper examines the impact of the openness of service trade on environmental pollution, so as to analyze the impact of the structure of international trade on environmental quality. In the formula,  $Service_{it}$  indicates the degree of openness of the service trade in each province, which is measured by the total value of service trade.  $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5,$  and  $\beta_6$  represent the elasticity coefficients of the composition effect, technology effect, scale effect, government environmental governance, foreign direct investment, and service trade, respectively;  $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5,$  and  $\theta_6$  are the elasticity coefficients of the spatial lags of the six explanatory variables.  $W$  is a spatial weight matrix, which is  $30 \times 30$ ;  $\rho$  refers to the local environmental pollution and direction and degree of spatial interaction of environmental pollution in adjacent areas;  $\tau$  and  $\eta$  are the response parameters of the dependent variable time lag term  $Z_{it-1}$  and the dependent variable time and space lag term  $WZ_{t-1}$ .  $\alpha$  is a constant term, and  $\mu_{it}$  is an individual fixed effect;  $\varepsilon_{it}$  is a random error term. Equation (3) is called the Dynamic Spatial Durbin Model. This model is used to estimate short-term and long-term direct effects, and short-term and long-term indirect (space spillover) effects.

According to theoretical analysis,  $\beta_1, \beta_2,$  and  $\beta_3$  are all negative values, indicating that the scale effect, composition effect, and technical effect can help to reduce pollution emissions and improve environmental quality.

The spatial weight ( $W$ ) can be explained as follows: the method proposed by Liu et al. (2017) is referred to in order to construct the economic distance spatial weight matrix [42]. The economic spatial weight is obtained based on the geographical space weight combined with a weight matrix that quantifies the economic differences between regions. The weight matrix to quantify economic differences between regions refers to a diagonal matrix of the proportion of the average GDP in each region to the average GDP. The trade studied in this article is an important part of the economy, so the economic weight matrix is used.

### 3.2. Data Description

Considering the availability of data and the consistency of the statistical methods, this paper selects 30 major provincial administrative divisions in China as the main analysis objects. The sample data are panel data of 30 provincial administrative divisions from 2007 to 2014. The 30 provincial administrative divisions used are Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

At the same time, in order to examine whether the development differences in different regions will bring about differences in the impact of trade on environmental quality, the regions are divided into two groups according to the differences in their regional GDP. The first group is the regions with a relatively high regional GDP. It is generally considered that China's Eastern coastal areas are regions with a higher degree of economic development. In this paper, Beijing, Tianjin, Shandong, Shanghai, Jiangsu, Zhejiang, and Guangdong were included in the Eastern coastal area group. The remaining provinces in the sample were included in the Central and Western regions.

The data of provinces from 2007 to 2014 were obtained from the public data of the National Bureau of Statistics of China. The provincial trade data used here were obtained from the China Business Yearbook 2007–2014. The descriptive statistics of the empirical analysis are shown in Table 1.

From 2007 to 2014, the average growth rate of the two types of environmental pollution in China was  $-10.416\%$  and  $-15.56\%$ , indicating that the average rate of environmental pollution in all provinces in China showed a downward trend. The average annual rate of change in the trade in goods and services is  $16.464\%$  and  $27.73\%$  from 2007 to 2014. The average trade data indicates that the average annual growth rate of China's provinces between 2007 and 2014 exceeded  $15\%$ . From the perspective

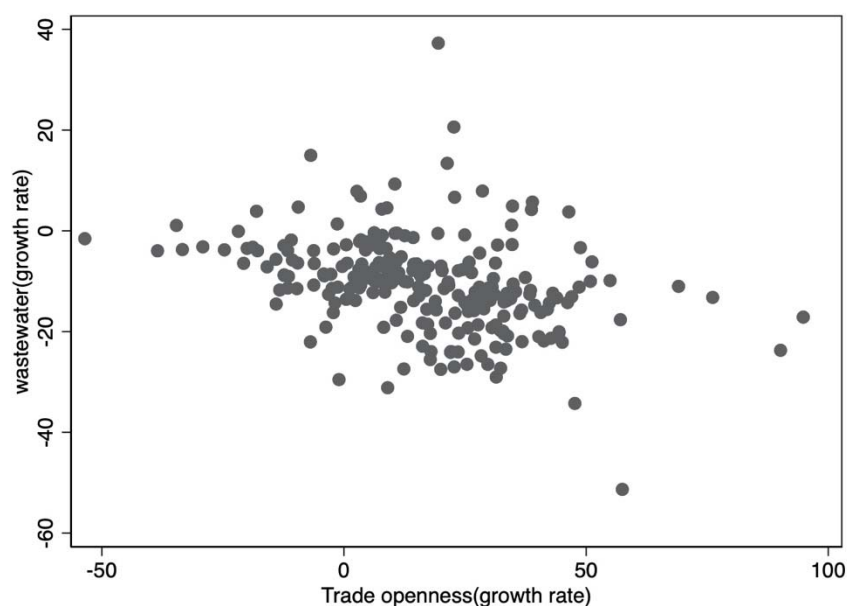


of average value, the trade in goods and services in China's provincial administrative divisions have shown a negative relationship with environmental pollution. Figure 1 shows the relationship between the growth rate of wastewater discharge and the increase rate of trade openness. The scatter plot shows a certain linear relationship, where the growth rate of wastewater discharge and the growth rate of trade openness are negatively correlated. An empirical analysis of the panel data was carried out to further study the impact of trade on environmental quality at a regional level.

**Table 1.** Descriptive statistics of variables.

Variable	Sample	Mean	Standard Error	Min	Max
Z	240	-10.416	9.48	-51.326	37.263
B	240	16.464	20.848	-53.515	94.832
I	240	14.72	7.097	0.074	37.009
KL	240	12.045	13.782	-21.856	71.075
Gov	240	15.214	79.423	-86.67	651.357
FDI	240	10.953	57.468	-59.776	581.335
Service	240	27.73	44.095	-80.933	274.901
SO2	240	-15.56	7.248	-52.933	12.144

Source: public data of the National Bureau of Statistics of China, the China Business Yearbook 2007–2014. Z represents the growth rate of environmental pollution measured by wastewater discharge; B represents the growth rate of technical effect; I represent growth rate of scale effect; KL represents the growth rate of the composition effect; Gov represents the growth rate of government environmental governance; FDI represents the growth rate of foreign direct investment; Variable Service represents the growth rate of trade in service; Variable SO2 represents the growth rate of sulfur dioxide emissions which is the measurement of environmental pollution in the robustness test.



**Figure 1.** Scatter plot of trade and wastewater discharge. Source: public data of the National Bureau of Statistics of China, the China Business Yearbook 2007–2014.

## 4. Empirical Analysis

### 4.1. Unit Root Test and Co-Integration Test

The assumption of the panel data model analysis is that the macroeconomic variables are stationary. In practice, macroeconomic variables may have a trend. In order to avoid the invalidity of the regression hypothesis caused by the trend, this paper conducted a logarithmic linearization of the variables to ensure that all variables are stationary. On the basis of logarithmic linearization, a unit root test was performed on the constructed measurement model to show the reliability of the test results. This paper used the software Stata 15.0 to perform the Levin, Lin, and Chu t test (LLC test) and Im, Pesaran,

and Shin test (IPS test) on the panel data. The unit test results indicate that all processed variable tests are rejected unit root assumptions. All variables were stationary after the logarithmic linearization process. The values of the LLC test and the IPS test were less than 0.05. Z, KL, B, I, Gov, FDI, and Service were integrated of order 1. Those selected in this paper are stationary.

In order to further determine whether there is a co-integration relationship between the variables, a co-integration test was performed on the panel data. There are three main methods for panel data co-integration inspection: the Pedroni test, the Kao test, and the Westerlund test. In order to strengthen the credibility of the panel co-integration test results, the Kao test (Kao, 1999), Pedroni test (Pedroni, 1999, 2004), and Westerlund test (Westerlund, 2005) were performed in the test section [43–46]. The cointegration test shows that there is a significant cointegration relationship among the variables of the panel data, which meets the assumptions of the panel data analysis.

#### 4.2. Dynamic Spatial Durbin Model Regression Analysis

Based on the analysis of the relevant theories and data above, the software Stata 15.0 was used to conduct an empirical analysis of the relationship between service trade, goods trade, and water environment pollution in Chinese provinces. Panel models are usually divided into fixed-effect panel models, random-effect panel models, or hybrid estimation models based on the test results of different models. The results show that the P-values for the F-test and Hausman test were zero, rejecting the null hypothesis. Thus, the fixed effect of the panel data is very significant.

Whether spatial effects need to be added to the econometric model depends on whether spatial autocorrelation characteristics exist in variables such as environmental pollution, trade in goods, income level, and trade in services in Chinese provinces. Therefore, this paper used the global Moran Index to measure whether there is a spatial autocorrelation in the geographical distribution of each variable. It can be seen from Table 2 that the Moran values of the four variables have been tested for significance in most years, indicating that China's environmental pollution, goods trade, income level, and service trade have obvious spatial dependence. The dependence is not obvious. Therefore, it is necessary to further investigate the relationship between trade development and environmental pollution by using the Spatial Durbin Model.

**Table 2.** Test results of spatial autocorrelation of variables.

Year	Z	p-Value	B	p-Value	I	p-Value	KL	p-Value
2007	0.179	0.000	0.014	0.026	0.014	0.029	0.021	0.025
2008	−0.028	0.047	0.100	0.006	0.027	0.023	0.087	0.007
2009	−0.048	0.042	0.010	0.029	−0.026	0.047	0.222	0.000
2010	−0.012	0.040	0.073	0.007	0.130	0.003	−0.056	0.037
2011	−0.026	0.046	0.052	0.014	0.239	0.000	−0.039	0.047
2012	−0.056	0.039	0.002	0.032	0.138	0.002	−0.016	0.042
2013	−0.022	0.045	−0.006	0.037	0.035	0.020	0.076	0.009
2014	−0.021	0.044	−0.082	0.027	−0.078	0.029	−0.077	0.030

Source: public data of the National Bureau of Statistics of China, the China Business Yearbook 2007–2014.

In order to determine the specific form of the model, the Moran's I test, the robust Lagrange multiplier (LM) test, Wald test, the likelihood ratio (LR) test, and Hausman test were performed, respectively. The test results showed that Moran's I passed the significance test at the 1% level. In addition, the results of the LM (Robust) test indicate that the null hypothesis was rejected, indicating that the model's residuals had spatial autocorrelation. The results of the LM (Robust) test tended to move to the Spatial Autoregressive Model (SAR). The specific form of the spatial panel model was further determined through the Wald test and the LR test. It was found that both the Wald test and the LR test rejected the null hypothesis at a significance level of 1%, indicating that the Spatial Durbin Model (SDM) is superior to the Spatial Error Model (SEM) and Spatial Autoregressive Model (SAR).

The Hausman statistic rejected the null hypothesis significantly at the 1% confidence level, indicating that the panel data is suitable for analysis under the fixed effects hypothesis.

Based on the SDM decomposition of the environmental quality effect of trade (Table 3), the total effect can be decomposed into two parts: the first part is the direct effect—that is, the local effect—which shows the impact of international trade on the region's trade. The other part is the indirect effect, which indicates the impact of the development of international trade in the region on environmental pollution in neighboring areas. The model is a Dynamic Spatial Durbin Model that can identify short-term direct effects and long-term direct effects. According to the decomposition results in Table 3, it is known that the direct effect coefficient of the scale effect in the short-term is  $-0.609$ , which is significant at the level of 1%. Every 1% increase in GDP per capita in the country will cause a 0.609% reduction in local environmental pollution. The long-term direct effect coefficient of the scale effect is  $-0.630$ , which is significant at the level of 1%, indicating that the growth of local per capita GDP contributes to a long-term reduction of environmental pollution. The estimated results of the composition effect coefficient show that in the short term, the coefficient of the direct effect is  $-0.097$ , which is very significant at the 5% level. The short-term and long-term estimated coefficients of technical effects are  $-0.024$  and  $-0.039$ , respectively. However, the estimates are not significant. The trade in services will curb environmental pollution in the short term. Among the short-term effects, the indirect suppression effect is more significant. The estimated coefficient is  $-0.183$ , which is very significant at the 1% level. The estimation results show that an increase of 1% in the growth rate of service trade in the region will help to reduce the growth rate of environmental pollution outside the region by 0.183%. The short-term impact coefficient of service trade on environmental quality is estimated at 0.195%, which is significant at the level of 1%. The long-term impact of trade in services on environmental quality is also significant. The trade in services within a region will have spillover effects on environmental quality outside the region. The long-term indirect impact of trade in services is estimated at 0.189%, and the overall long-term impact is 0.201%. Foreign direct investment has an indirect suppression effect on environmental pollution. The short-term indirect effect is  $-0.090$ , which is very significant at the 5% level. The long-term indirect impact of foreign direct investment is estimated at  $-0.093$ , which is very significant at the 5% level. The estimated government governance coefficient is negative in both the short-term and long-term, but the empirical results are not significant.

**Table 3.** Model results of 30 Chinese provinces.

Variable	SR Direct	SR Indirect	SR Total	LR Direct	LR Indirect	LR Total
B	-0.024 (-0.70)	-0.013 (-0.10)	-0.038 (-0.29)	-0.025 (-0.70)	-0.013 (-0.10)	-0.039 (-0.29)
I	-0.609*** (-4.42)	0.21 -0.51	-0.399 (-0.97)	-0.630*** (-4.42)	0.219 -0.52	-0.411 (-0.97)
KL	-0.097** (-2.22)	0.107 -0.84	0.01 -0.08	-0.101** (-2.22)	0.111 -0.84	0.01 -0.08
Service	-0.012 -0.63	-0.183*** -2.77	-0.195*** -2.63	-0.012 -0.63	-0.189*** -2.76	-0.201*** -2.62
FDI	0.007 -0.68	-0.090** (-2.15)	-0.083* (-1.89)	0.007 -0.69	-0.093** (-2.14)	-0.086* (-1.89)
Gov	-0.008 (-1.34)	-0.001 (-0.07)	-0.01 (-0.44)	-0.008 (-1.34)	-0.001 (-0.07)	-0.01 (-0.44)

Standard errors are in parentheses. \*\*\* represents  $p < 0.01$ ; \*\* represents  $p < 0.05$ ; \* represents  $p < 0.1$ .

#### 4.3. Regional Analysis

In the literature review, the regional economic development differences are also a factor that cannot be ignored. In this paper, the 30 provinces across the country are classified according to the classification of the Eastern coastal areas and the Central and Western regions. The regression results are shown in Tables 4 and 5. Table 4 shows the dynamic spatial econometric regression results for



the Eastern region. Table 5 shows the dynamic spatial econometric regression results for the Central and Western regions. The regression results of the Eastern coastal areas show that the short-term direct effect estimated coefficient of the technical effect is 0.418, which is significant at the 1% level. The long-term direct effect of the technical effect is estimated at 0.514, which is significant at the 1% level. It shows that the technical effect does not inhibit the environmental pollution. An increase in the growth rate of the goods trade will also cause an increase in the growth rate of environmental pollution. A possible explanation for this phenomenon is that the total goods trade in the Eastern coastal areas is relatively large. Pursuing excess trade in goods will sacrifice environmental quality. The estimated short-term and long-term direct effects of the scale effects are 0.731 and 0.877, which are significant at the 10% level. The estimated results of the structural effects show the same characteristics. The slowdown in the growth of the capital–labor ratio will help improve the quality of the environment. At the same time, as part of international trade, the influence coefficient of trade in services is negative. However, the significance test cannot reject the hypothesis that the coefficient is zero.

**Table 4.** Regression model results of the Eastern samples.

Variable	SR Direct	SR Indirect	SR Total	LR Direct	LR Indirect	LR Total
B	0.418*** −3.68	−0.381 (−1.46)	0.0367 −0.14	0.514*** −3.66	−0.473 (−1.51)	0.0412 −0.13
I	0.731* −2.32	0.783 −1.16	1.514 −1.68	0.877* −2.3	0.906 −1.09	1.784 −1.62
KL	0.185*** −3.73	0.0964 −0.71	0.281* −1.97	0.223*** −3.65	0.108 −0.65	0.331 −1.91
Service	−0.0552 (−1.12)	−0.217 (−1.89)	−0.272 (−1.86)	−0.0638 (−1.06)	−0.257 (−1.82)	−0.321 (−1.80)
FDI	0.135** −2.98	−0.119 (−1.04)	0.0161 −0.12	0.166** −2.98	−0.148 (−1.09)	0.0181 −0.12
Gov	0.00322 −0.46	−0.0198 (−1.29)	−0.0166 (−1.04)	0.00422 −0.49	−0.0238 (−1.28)	−0.0196 (−1.02)

Standard errors are in parentheses. \*\*\* represents  $p < 0.01$ ; \*\* represents  $p < 0.05$ ; \* represents  $p < 0.1$ .

**Table 5.** Regression model results of Central and Western samples.

Variable	SR Direct	SR Indirect	SR Total	LR Direct	LR Indirect	LR Total
B	−0.312* (−2.27)	−0.53 (−0.90)	−0.843 (−1.41)	−0.677* (−2.11)	−1.222 (−0.51)	−1.899 (−0.77)
I	0.441 −1.21	−1.55 (−1.03)	−1.108 (−0.70)	1.012 −1.1	−3.533 (−0.43)	−2.52 (−0.29)
KL	−0.148 (−1.39)	0.907** −2.7	0.759* −2.19	−0.351 (−1.26)	2.084 −0.82	1.733 −0.65
Service	0.00527 −0.14	−0.0639 (−0.44)	−0.0586 (−0.35)	0.0137 −0.15	−0.146 (−0.21)	−0.133 (−0.17)
FDI	0.00783 −0.38	0.0343 −0.39	0.0422 −0.45	0.0164 −0.35	0.0775 −0.28	0.0939 −0.33
Gov	−0.0494*** (−3.47)	−0.0325 (−0.67)	−0.0818 (−1.57)	−0.108** (−3.25)	−0.0749 (−0.31)	−0.183 (−0.73)

Standard errors are in parentheses. \*\*\* represents  $p < 0.01$ ; \*\* represents  $p < 0.05$ ; \* represents  $p < 0.1$ .

The regression results for the Central and Western regions are different from those for the Eastern coastal regions. The technical effect estimates show that the estimated coefficient of the short-term direct effect is −0.312, which is significant at a significance level of 10%. The estimated long-term direct effect of the technical effect is −0.677, which is significant at a significance level of 10%. The estimation results of short-term effects and long-term effects indicate that technical effects can help to restrain the growth rate of environmental pollution in the short-term and long-term. Each 1% increase in the rate of increase in the trade in goods helps to reduce the increase in environmental pollution in

the region by 0.312 in the short-term and 0.677% in the long-term. In the short-term, the estimated results of the scale effects are positive, while the long-term effects are negative. The estimated results of the structural effects indicate that the increase in the capital–labor ratio by 1% in the short-term will cause an increase in the growth rate of environmental pollution by 0.759%. The short-term overall effect of the capital–labor ratio is 0.759, which is significant at the 10% level. In the estimation results of the Central and Western regions, the estimates of the trade in services and international direct investment are not significant. The government’s control of environmental pollution has a promoting effect on the reduction of environmental pollution in the region. The estimated short-term direct effect of government governance is  $-0.0494\%$ , which is significant at the 1% level. The influence coefficient of government governance on the growth of environmental pollution in the region is  $-0.108$ , which is significant at a significance level of 5%.

## 5. Robustness Test

In order to analyze the impact of international trade on environmental pollution, this paper chooses another environmental pollution indicator to measure the environmental pollution in different provinces. Wastewater discharge reflects only one aspect of environmental pollution. Choosing another measurement from the perspective of air pollution helps to further verify the impact of international trade in goods and services on environmental pollution, and selecting sulfur dioxide emissions as a measurement index helps to avoid the differences in the emissions of pollutants in industrial production in different regions. The robustness test adopts the same analysis method, with the same explanatory variables and control variables to examine the environmental quality effects of trade. Therefore, the robustness of the conclusion and the validity of the method can be verified.

The regression results of the Dynamic Spatial Durbin Model, using sulfur dioxide emissions as explanatory variables of environmental pollution, show that the estimated short-term direct effect coefficient of the scale effect is  $-1.143$ , which is significant at the level of 1% (see Table 6). The estimated long-term direct effect coefficient is  $-1.026$ , which is significant at the 1% level. The estimation results show that for every 1% increase in the growth rate of per capita income in the Central and Western regions, the growth rate of environmental pollution can be reduced by 1.143% in the short-term, and the growth rate of environmental pollution by 1.026% in the long-term. The scale effects have spillover effects on environmental pollution outside the region in the short-term. The estimated short-term indirect effect coefficient is 2.246, which indicates that a 1% increase in the growth rate of the capital–labor ratio in the region will cause an increase in environmental pollution outside the region by 2.246%. The estimated long-term indirect effect coefficient is 1.809, which is significant at the 1% level. A possible explanation for this phenomenon is that the increase in the growth rate of per capita GDP has a certain promoting effect on the environmental pollution outside the region. The changes in per capita income have spatial characteristics and will cause changes in the scale of production of polluting and cleaning products outside the region. The structural effects and technical effects were not significant in the regression results. The suppression effect of service trade on regional environmental pollution was not significant in the entire sample.

Table 7 shows the regression results in the Eastern coastal areas. The first to third columns are the short-term effects of each variable on the increase rate of sulfur dioxide emissions, and the fourth to sixth columns are the long-term effects of each variable on the increase rate of sulfur dioxide emissions. Each 1% increase in the growth rate of trade in goods will cause an increase in the growth rate of sulfur dioxide emissions outside the region by 0.588, which will affect the short-term total effect by 0.697%. Among the long-term effects, the coefficient of the indirect effect of trade in goods on the growth rate of sulfur dioxide is 0.732, which is significant at the level of 5%. The data shows that the trade in goods has a spillover effect on environmental pollution outside the region. Each increase of 1% in the growth rate of trade in goods will cause a 0.732% increase in the sulfur dioxide emission rate. The estimated results of the scale effect are significant. In the short term, a 1% increase in the growth rate of per capita income will help to increase the growth rate of sulfur dioxide emissions in the region by 0.67%. The estimated

result of the coefficient is significant at the 5% level. The estimated short-term indirect effect of per capita income is 1.135, which is significant at the 5% level. The long-term effect estimates indicate that the direct impact coefficient of per capita income growth on environmental pollution is 0.869 and the indirect impact coefficient is 1.485. The estimated long-term effect of the scale effect is 2.253, which is significant at a significance level of 1%. The overall effect of the structural effect is estimated to be negative, but it does not reach the significance level of 10%. It is worth noting that, as a part of international trade, the service coefficient on local environmental pollution in the short term is  $-0.0866$ , which is significant at a significance level of 10%. The short-term impact coefficient of service trade on environmental pollution outside the region is  $-0.112$ , and the overall impact coefficient is  $-0.198$ , which is significant at the level of 10%. The long-term effect coefficient estimation results show that the influence coefficient of service trade on the growth of environmental pollution in the region is  $-0.109\%$ , and the influence coefficient of environmental pollution outside the region is  $-0.149\%$ . The estimated coefficient of the overall effect is  $-0.258$ , which is significant at the level of 10%.

**Table 6.** Regression model results of the Eastern, Central, and Western samples.

Variable	SR Direct	SR Indirect	SR Total	LR Direct	LR Indirect	LR Total
B	0.0798 −1.74	0.0923 −0.66	0.172 −1.23	0.0649 −1.64	0.0581 −0.56	0.123 −1.23
I	−1.143*** (−5.31)	2.246*** −3.77	1.103 −1.82	−1.026*** (−5.55)	1.809*** −4.14	0.783 −1.85
KL	0.043 −0.77	−0.154 (−1.05)	−0.111 (−0.75)	0.0405 −0.84	−0.119 (−1.09)	−0.0788 (−0.75)
Service	−0.00874 (−0.41)	0.0761 −1	0.0674 −0.8	−0.00945 (−0.54)	0.0571 −1.04	0.0476 −0.8
FDI	0.00425 −0.34	−0.0529 (−1.28)	−0.0487 (−1.18)	0.00502 −0.47	−0.0396 (−1.30)	−0.0346 (−1.20)
Gov	0.00421 −0.58	−0.0227 (−0.99)	−0.0185 (−0.82)	0.00417 −0.66	−0.0173 (−1.01)	−0.0132 (−0.82)

Standard errors are in parentheses. \*\*\* represents  $p < 0.01$ ; \*\* represents  $p < 0.05$ ; \* represents  $p < 0.1$ .

**Table 7.** Regression model results of the Eastern samples.

Variable	SR Direct	SR Indirect	SR Total	LR Direct	LR Indirect	LR Total
B	0.109 −0.78	0.588** −2.88	0.697*** −5.38	0.176 −1.19	0.732** −3.11	0.908*** −5.15
I	0.670** −2.6	1.135** −2.93	1.805*** −4.06	0.869** −2.93	1.485** −3.05	2.353*** −3.92
KL	0.017 −0.3	−0.034 (−0.34)	−0.017 (−0.24)	0.0166 −0.28	−0.0391 (−0.34)	−0.0225 (−0.24)
Service	−0.0866* (−1.98)	−0.112 (−1.39)	−0.198* (−2.49)	−0.109* (−2.24)	−0.149 (−1.54)	−0.258* (−2.45)
FDI	0.0722 −1.5	−0.0662 (−0.87)	0.00597 −0.09	0.0775 −1.49	−0.0696 (−0.78)	0.00785 −0.09
Gov	−0.00626 (−0.79)	−0.00244 (−0.19)	−0.0087 (−1.10)	−0.00742 (−0.90)	−0.00392 (−0.27)	−0.0113 (−1.09)

Standard errors are in parentheses. \*\*\* represents  $p < 0.01$ ; \*\* represents  $p < 0.05$ ; \* represents  $p < 0.1$ .

In the regression results of the central and western regions, the direct effect estimation coefficient of the technical effect is significant at a significance of 10% (see Table 8). The short-term influence coefficient is 0.212, and the long-term influence coefficient is 0.205. The estimation results show that for every 1% increase in the growth rate of trade in goods, the direct effect in the short term is 0.212%, and the direct effect in the long term is 0.205%. The estimation results show that the scale effect is significant in the Central and Western regions. The estimated short-term direct effect coefficient of GDP per capita is  $-1.278$ , which is significant at the level of 1%. The estimated coefficient of long-term

direct effects is  $-1.353$ , which is significant at the 1% level. The scale effects have spillover effects on environmental pollution outside the region. The increase in the per capita GDP growth rate in the region has a short-term impact coefficient of 1.606 on the growth rate of environmental pollution outside the region, which is significant at the level of 10%. The estimated long-term impact coefficient is 1.783, which is significant at the 10% level.

**Table 8.** Regression model results of the Central and Western samples.

Variable	SR Direct	SR Indirect	SR Total	LR Direct	LR Indirect	LR Total
B	0.212*	0.218	0.43	0.205*	0.149	0.354
	-2.15	-0.7	-1.42	-1.99	-0.55	-1.43
I	-1.278***	1.806*	0.527	-1.353***	1.783*	0.431
	(-4.76)	-2.17	-0.63	(-4.87)	-2.49	-0.63
KL	0.0647	-0.0326	0.0321	0.0663	-0.0397	0.0266
	-0.86	(-0.18)	-0.18	-0.85	(-0.26)	-0.19
Service	-0.00184	0.0886	0.0867	-0.00514	0.0762	0.071
	(-0.07)	-0.99	-0.87	(-0.20)	-1.02	-0.87
FDI	-0.00344	-0.0382	-0.0417	-0.00203	-0.0322	-0.0342
	(-0.23)	(-0.86)	(-0.93)	(-0.13)	(-0.84)	(-0.94)
Gov	0.0111	-0.0333	-0.0222	0.0124	-0.0306	-0.0182
	-1.14	(-1.33)	(-0.87)	-1.24	(-1.40)	(-0.87)

Standard errors are in parentheses. \*\*\* represents  $p < 0.01$ ; \*\* represents  $p < 0.05$ ; \* represents  $p < 0.1$ .

## 6. Conclusions

The research objectives of this article are to examine the impact of international trade on China's provincial environmental quality. Based on the existing theoretical analysis framework of the scale effect, composition effect, and technical effect of trade on environmental quality, this paper selected data on goods trade and total wastewater discharge from 30 provincial administrative divisions in China from 2007 to 2014. This paper analyzed the impact of international trade on the environmental quality of China's provinces with panel data analysis. To ensure the robustness of the empirical results, this paper conducted a unit root test and co-integration tests on the data. The fixed-effect panel data analysis method was determined by a Hausmann test. The Moran Index was calculated for variables of the regression to determine spatial heterogeneity. In addition, this paper replaced the measurement of environmental pollution with the emission of sulfur dioxide to build a robustness test that could ensure the stability of the method and the credibility of the conclusion.

According to the research results, the impact of international trade on the environmental quality of China's provinces is significant. The following characteristics were observed in the results: (1) the development of international trade is conducive to the improvement of environmental quality and helps to reduce the growth rate of environmental pollution. The scale effect and composition effect are conducive to curbing the growth of environmental pollution. The coefficient of the scale effect is higher than that of the composition effect. Increasing per capita income is an effective way to reduce environmental pollution in China's provinces. In the empirical results, with wastewater discharge as an indicator of environmental pollution, every 1% increase in the growth rate of per capita income can reduce the growth rate of environmental pollution by 0.609% in the short-term and 0.603% in long-term. Increasing the growth rate of the capital-labor ratio by 1% can reduce the growth rate of environmental pollution by 0.097% in the short-term and 0.101% in the long-term, and the growth in the service trade is conducive to decrease the growth of pollution emission. The service trade could help regions that are connected to the observed region. The coefficient is  $-0.183$  in the short run and  $-0.189$  in the long run. In the robustness test, the increase in trade in services has helped to reduce the growth rate of sulfur dioxide emissions in the Eastern coastal areas. The short-term total impact coefficient is  $-0.198$ , and the long-term total impact coefficient is  $-0.258$ . (2) Regional studies have shown that the scale effect in the Eastern coastal areas of China represents the main trade-induced

environmental effect. The composition and technical effect are also significant in the Eastern coastal provinces. In the Central and Western regions, the main effect of trade on environmental quality arises from the scale effect. The composition and technical effect are also significant here, but their coefficients are small. Therefore, the difference in the degree of regional economic development has an impact on the environmental effects of trade. In areas where the economy is relatively well-developed, the effect of the goods trade is not beneficial for the control of pollution, according to the regression results. The explanation for this phenomenon may be derived from the regions with better economic development, where the capital–labor ratio and technical level reach a higher level, and the marginal effect on the improvement of environmental quality tends to decrease. (3) In the empirical analysis of the Central and Western regions, the technical effects of trade on the environment are significant, helping to curb the growth of environmental pollution. Government governance is also an aspect of reducing environmental pollution. In the robustness test, while using sulfur dioxide as a measure of environmental pollution, the above conclusions were verified.

Therefore, in the context of increasing restrictions on economic development in the current environment, international trade is an effective method to enhance the sustainability of regional economic development. The increase in the size of international trade and the optimization of the trade structure are conducive to the reduction of environmental pollution emissions, thereby improving the quality of the environment, and, thus, achieving the goal of sustainable development. In the process of the economic development of the region, it is necessary to combine the status quo of economic development in the region and make full use of the scale effect, composition effect, and technical effect in order to change the intensity of pollution emissions of products and the allocation of factor resources to achieve the sustainability of economic development. In terms of trade structure, the development of the service trade helps to improve the trade structure and reduce the proportion of polluting products in trade, which is beneficial for realizing the optimization of products in the trade structure and reducing the intensity of pollution.

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