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RESEARCH ARTICLE

Trade openness and pollutant emissions in China: the role of capital abundance and income

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Abstract

The role of capital abundance and income in the trade openness and environmental quality debate has long been a concern among academic researchers. The researchers of this paper empirically analyze the effects of trade and other core factors on emissions of four pollutants (SO_2, SM, VOC, and NH_X), using panel data from 31 provinces in China from 2000 to 2015. Then the scale, composition, technique, and trade elasticities are calculated, based on lower and higher levels of capital abundance and relative income. Furthermore, the researchers calculate the province-specific trade elasticities and analyze the relationship between the province-specific trade elasticities and capital abundance and relative income, respectively. They find a negative effect of trade openness on pollutant emissions in China. The analysis of the elasticities in terms of China's pollutant emissions shows that the scale and composition elasticities are positive, while technique and trade elasticities are negative. Moreover, provinces with lower capital abundance tend to have more negative trade elasticities, while provinces with higher relative income tend to have more negative trade elasticities. The result implies that both pollution haven effect and factor abundance effect may be at work in Chinese provinces, but the dominance of one effect over the other depends on a province's level of capital abundance and income.

Keywords Trade openness · Pollutant emissions · Capital abundance · Income · Elasticity

Introduction

According to the National Bureau of Statistics, China's import and export trade reached 24,584.9 billion yuan in 2015, ranking second in the world. Since China's reform and opening up in 1978, the rapid development of its foreign trade has greatly promoted its economic growth, technological progress, and social welfare improvement. However, reports on environmental pollution in China have endlessly emerged. For example, the successive emergence of haze weather in various cities throughout China shows that the air quality has obviously been worsen; the poisonous fish event of Luo Jia Lake indicates that the water pollution problems are continuously aggravated in China; due to serious environmental pollution, one-third of the land in China has been contaminated by acid rain, and more than 300 million farmers do not have clean water to drink. According to the Ministry of Ecology and Environment of the People's Republic of China, China's emissions of sulfur dioxide (SO_2) reached 18.591 million tons in 2015, ranking first in the world; its emissions of industrial smoke (SM) reached 12.326 million tons, emissions of chemical oxygen demand (COD) reached 29.345 million tons, and emissions of ammonia nitrogen (NH_X) reached 0.217 million tons, these three ranking second in the world.

However, in the research on the environmental effects of trade, there generally exist two significant streams. One stream of research argues that trade accelerates the exploitation and utilization of the natural resources, consequently speeding up the pace of environmental degradation (Sanchez-Choliz and Duarte 2003; Mongelli et al. 2006; Levinson 2009; Davis and Kahn 2010; Chebbi et al. 2011;

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Mahmood et al. 2019; Yao et al. 2019). Another view holds that trade openness increases the income of a country, which can help the country formulate tighter environmental standards, and thus plays a role in improving the environmental quality (Antweiler et al. 2001; Frankel and Rose 2005; Gamper-Rabindran 2006; Gutierrez and Teshima 2011; Forslid et al. 2015; Holladay 2016; Shapiro 2016; Jevan 2017; Yasmeen et al. 2018).

Previous studies on the effect of trade openness on pollutant emissions can be divided into three strands of research. The first concentrates on "pollution haven hypothesis" (PHH), which posits that trade liberalization can make polluting industries moved from a country with tight environmental regulation and high income to another country with loose environmental regulation and low income (Antweiler et al. 2001; Taylor 2004; Frankel and Rose 2005; Levinson and Taylor 2008; Martin 2012; Le et al. 2016). For example, Le et al. (2016) argue that trade openness had a harmful effect on the environment in middle- and low-income countries, but a benign effect on the environment in high-income countries, and this result was consistent with the "pollution haven hypothesis," which posits that rich countries with tight environmental regulations dump pollution on poor countries with loose regulations. The second strand of research is mostly devoted to the analysis of the "factor endowment hypothesis" (FEH), which holds that countries with abundant capital have comparative advantages in the production of capital-intensive industries (Cole and Elliott 2003; Derek 2008; Cui et al. 2016; Wen and Dai 2020). Since capital-intensive industries are usually the pollution-intensive industries, countries with abundant capital have comparative advantages in pollution-intensive industries (Dean 2002; Dean et al. 2009; Cole 2004). The third strand of studies investigate the environmental Kuznets curve (EKC), which is used to analyze the relationship between the economic development and the environment. These studies have shown that the increase in per capita income would lead to the environmental degradation in the early stage of economic development, but once the economic growth exceeds a certain threshold, the increase in per capita income can improve environmental quality (Maddison 2006; Dean and Lovely 2010; Mahmood, 2019). For example, Pata (2019) argues that the results of the long-run estimators of Turkey indicated that the inverted U-shaped EKC hypothesis was valid and trade openness promoted carbon dioxide emissions, but income in Turkey had not yet reached the necessary threshold to reduce pollution.

As capital abundance and relative income play significant roles in the mutual relationship between trade and the environment, scholars have carried out a number of useful explorations in this field. Derek (2008), for instance, was motivated by Antweiler et al. (2001). He analyzed what role income may play in trade and the environment based on the data of 128 developed and developing countries. Finally, he found that in the countries whose relative incomes were more than 2.5, if trade openness increased by 1%, pollutant emissions would decrease by 0.5 to 11%, while in countries whose relative incomes were less than 0.5, with the same change in trade openness as the above, the pollutant emissions would increase by 0.3 to 0.5%. However, according to the decomposition of elasticities of Antweiler et al. (2001), there still exists a research gap of the environmental effect of China's trade openness, especially China's trade elasticity from the perspective of capital abundance and relative income simultaneously. To fill in this gap, the current study empirically examines the environmental effect of trade and other core factors; analyzes the scale, composition, technique, and trade elasticities based on different relative capital-labor ratios and relative incomes; further analyzes the province-specific trade elasticity; and considers the relationship between province-specific trade elasticity and capital abundance and relative income on the basis of panel data of the 31 provinces of China from 2000 to 2015.

More concretely, the present study contributes to the existing literature by addressing three questions about trade and pollution. First, is trade good or bad for China's environmentally sustainable development? In this regard, the present paper conducts an empirical analysis on the environmental effect of China's trade based on the empirical model of Antweiler et al. (2001). This paper analyzes the same question as Antweiler et al. (2001) and Derek (2008), but does so using different data sources. The second contribution of this paper is that the researchers calculate China's scale, composition, technique, and trade elasticities on the basis of different relative capital-labor ratios and relative incomes. This decomposition of the elasticities sheds light on how intensively trade and other core factors affect China's environmental quality, which makes this study different from the existing studies. The third valuable contribution of this paper is that the researchers calculate China's province-specific trade elasticity and analyze the relationship between the province-specific trade elasticity and relative capital-labor ratio and relative income. Finally, from a robust methodological point of view, this study applies more appropriate panel econometric techniques, such as SUR and 2SLS, and uses the shortest distance among the distances from the provincial capital to Shanghai Port, Tianjin Port, and Hong Kong Port as the instrumental variable for trade openness to solve the possible reverse causality. Then this paper also conducts a counterfactual analysis on the trade elasticity for a 5% increase in trade openness to guarantee the robustness of the conclusions. In short, the purpose of the current research is to (i) complement the recent literature that examines the relationship between trade openness and SO_2, SM, VOC, and NH_X emissions based a dataset and evidence from China; (ii) conduct the decomposition of the elasticities for analyzing the effects of economic scale, economic composition, per capita income, and trade openness on pollutant emissions, from a new perspective considering capital abundance and relative income; and (iii) calculate China's province-specific trade elasticity to analyze the relationship between the province-specific trade elasticity and capital abundance and relative income. The rest of the paper is as follows: Section 2 presents the econometric model specifications, a description of the variables, and the details about the dataset in the section on the "Model setting and data description". Section 3 presents and explains the empirical results. The last section summarizes the conclusions and provides policy implications.

Model setting and data description

Model setting

For the analysis of the environmental effect of trade of the 31 provinces in China from 2000 to 2015, the empirical strategy adopted here is based on the estimation equation of Antweiler et al. (2001), that is, the total emissions in a country are a function of economic scale, economic composition, per capita income, and trade openness. Based on the equations of Antweiler et al. (2001) and Derek (2008), the following econometric model can be deduced:

$$Z_{git} = \alpha_0 + \alpha_{g1}\mathrm{SCALE}_{it} + \alpha_{g2}\mathrm{KL}_{it} + \alpha_{g3}\mathrm{INC}_{it} + \alpha_{g4}\Psi_{git}\mathrm{TI}_{it} + \lambda_i + \lambda_t + \varepsilon_{git} \quad (1)$$

In the Formula (1),

$$\Psi_{git} = \Psi_{g0} + \Psi_{g1}\mathrm{REL.KL}_{it} + \Psi_{g2}\mathrm{REL.KL}_{it}^2 + \Psi_{g3}\mathrm{REL.INC}_{it} + \Psi_{g4}\mathrm{REL.INC}_{it}^2 \quad (2)$$

Then, the following equation can be obtained:

$$Z_{git} = \alpha_0 + \alpha_{g1}\mathrm{SCALE}_{it} + \alpha_{g2}\mathrm{KL}_{it} + \alpha_{g3}\mathrm{INC}_{it} + \alpha_{g4}\Psi_{g0}TI_{it} + \alpha_{g4}\Psi_{g1}\mathrm{TI}_{it}\times\mathrm{REL.KL}_{it} + \alpha_{g4}\Psi_{g2}\mathrm{TI}_{it}\times\mathrm{REL.KL}_{it}^2 + \alpha_{g4}\Psi_{g3}\mathrm{TI}_{it}\times\mathrm{REL.INC}_{it} + \alpha_{g4}\Psi_{g4}\mathrm{TI}_{it}\times\mathrm{REL.INC}_{it}^2 + \lambda_1 + \lambda_t + \varepsilon_{git} \quad (3)$$

To analyze the nonlinear relationships between capital-labor ratio and pollutant emissions, the nonlinear relationship between per capita income and pollutant emissions, and the impact of the interaction of economic composition (capital-labor ratio) and environmental regulation (per capita income) on pollutant emissions, this paper further obtains the following equation:

$$Z_{git} = \alpha_0 + \alpha_{g1}\mathrm{SCALE}_{it} + \alpha_{g2}\mathrm{KL}_{it} + \alpha_{g2}^{'}\mathrm{KL}_{it}^2 + \alpha_{g3}\mathrm{INC}_{it} + \alpha_{g3}^{'}\mathrm{INC}_{it}^2 + \alpha_{g23}\mathrm{KL}_{it}\times\mathrm{INC}_{it} + \alpha_{g4}\Psi_{g0}\mathrm{TI}_{it} + \alpha_{g4}\Psi_{g1}\mathrm{TI}_{it}\times\mathrm{REL.KL}_{it} + \alpha_{g4}\Psi_{g2}\mathrm{TI}_{it}\times\mathrm{REL.KL}_{it}^2 + \alpha_{g4}\Psi_{g3}\mathrm{TI}_{it}\times\mathrm{REL.INC}_{it} + \alpha_{g4}\Psi_{g4}\mathrm{TI}_{it}\times\mathrm{REL.INC}_{it}^2 + \lambda_1 + \lambda_t + \varepsilon_{git} \quad (4)$$

In the above equation, Z_{git} is the emission of pollutant g in region i in year t. The study examines four kinds of pollutants, which involve two air pollutants, sulfur dioxide (SO_2) and industrial smoke (SM), and two water pollutants—chemical oxygen demand (COD) and ammonia nitrogen (NH_X). SCALE_{it} is the GDP in region i in year t, which represents the economic scale; KL_{it} refers to the capital-labor ratio in region i in year t, which represents the degree of capital abundance and the economic composition and is measured by the ratio of the gross social investment in fixed assets to total employment in the region; INC_{it} is the per capita income in region i in year t, which represents the stringency of the environmental regulation and is measured by the average monetary wages of the staff; TI_{it} means the degree of trade openness in region i in year t, which represents the degree of trade openness and is measured by the ratio of the gross export-import volume to the GDP in the region; λ_i and λ_t are the province fixed effect and time fixed effect, respectively; the values of α_{g1}, α_{g2}, α_{g3}, and $\alpha_{g4}\Psi_{git}$ are the influences of economic scale, economic composition, per capita income, and trade openness on pollutant emissions, respectively. According to Antweiler et al. (2001), $\alpha_{g1} > 0$, $\alpha_{g2} > 0$, and $\alpha_{g3} < 0$, that is, pollutant emissions are expected to increase with the economic scale and capital intensity but decrease with per capita income. However, predictions with respect to the parameters $\alpha_{g4}\Psi_{git}$ are difficult to make, because they are region-specific and depend on the capital-labor ratio and per capita income in the regions.

REL. KL_{it} is the relative capital-labor ratio in region i in year t, which is measured by the ratio of regional capital-labor ratio to average national capital-labor ratio; REL. INC_{it} refers to the relative per capita income in region i in year t, which is measured by the ratio of regional per capita income to average national per capita income.

KL_{it}^2 is the quadratic term of the capital-labor ratio, which reflects the nonlinear relationship between the capital-labor ratio and pollutant emissions; INC_{it}^2 is the quadratic term of the per capita income, which reflects the nonlinear relationship between per capita income and pollutant emissions; $\mathrm{KL}_{it}\times\mathrm{INC}_{it}$ is the cross term of the capital-labor ratio and the per capita income, which reflects the impact of the interaction of economic composition (capital-labor ratio) and environmental regulation (per capita income) on pollutant emissions.

$\mathrm{TI}_{it}\times$ REL. KL_{it} is the cross term of trade openness and relative capital-labor ratio. Theoretically, if the relative capital-labor ratio of one region is higher than that of other regions, the comparative advantage of capital-intensive industries and pollution industries caused by trade openness will be larger. The quadratic term reflects that the comparative advantage influenced by the relative capital-labor ratio might be nonlinear. That is, $\alpha_{g4}\Psi_{g1} > 0$, but the expected symbol of $\alpha_{g4}\Psi_{g2}$ is indefinite.

Similarly, $TI_{it} \times REL.\ INC_{it}$ is the cross term of trade openness and relative per capita income. Theoretically, if the relative income and environmental regulation level of one region are higher than those of other regions, the comparative advantage of clean industries caused by trade openness is larger. The quadratic term reflects that the comparative advantage influenced by the relative per capita income should be nonlinear, namely, $\alpha_{g4}\Psi_{g3} < 0$, but the expected symbol of $\alpha_{g4}\Psi_{g4}$ is indefinite.

Data description

The data, including social fixed asset investment, employment, average monetary wages of staffs, gross export-import volume, and GDP for this study, are from China's Statistical Yearbook (http://www.stats.gov.cn/tjsj/ndsj/); the data on SO_2, SM, COD, and NH_X emissions are from China's Environmental Statistical Yearbook (http://www.mee.gov.cn/hjzl/sthjzk/sthjtjnb/). The final panel datasets cover both sectional units of China's 31 provinces and time series from 2000 to 2015 with 496 sample observations in total. To eliminate the errors brought about by price factors, GDP, average monetary wages of the staff, and gross export-import volume are converted to the actual prices by using the consumer price index (CPI); social fixed asset investment is converted to the actual price with the price index of investment in fixed assets. Since the price index of investment in fixed assets takes the year 1991 as the base period and the consumer price index takes the year of 1978 as the base period, the researchers convert the above two indexes taking the year of 2000 as the base period. Table 1 provides descriptive statistics of the data. Then they conduct a correlation analysis on the relationship between the average value of trade openness and the average value of emissions of SO_2, SM, COD, and NH_X from 2000 to 2015 for China's 31 provinces, which is shown in Appendix Fig. 3. It can be clearly seen from Appendix Fig. 3 that there exist negative correlations between trade openness and emissions of SO_2, SM, COD, and NH_X. Appendix Table 9 provides the names and corresponding province codes of the 31 provinces in China.

Empirical results and discussion

Basic results

Unit root test

To avoid the pseudo regression, the researchers conduct unit root test for the correlated variables. Firstly, the 1st generation panel unit root tests, namely, LLC and IPS, are employed, and the results are shown in Table 2. Secondly, to solve the possible cross-sectional correlation in panel data and ensure the robustness of the result, the 2nd generation panel unit root tests, namely, CIPS and Pescadf, are further used in this paper, and the results are also shown in Table 2. As can be seen from Table 2, the test results indicate that the null hypothesis of the unit root cannot be rejected; however, after the first-order difference is carried out, the test results suggest that the null hypothesis of unit root is rejected at least at the significance level of 10%, indicating that all the variables are first-order single integer sequences and that there is no cross-sectional correlation.

The effects of trade and other core factors on the environment

Then, the researchers introduce the 496 sample observations into Formula (4) to establish 31 equations and use the seemingly unrelated regression(SUR) method to carry out regression analysis. The results are shown in Table 3.

From Table 3, the impacts of SCALE on the emissions of the four pollutants are all positive, indicating that the expansion of economic scale gives rise to the deterioration of the environmental quality in China. The results are in accordance with those of Strutt and Anderson (1999) and Antweiler et al.

Table 1 Data description

Variable	Obs.	Mean	Median	Std. dev.	Min	Max
SO_2 (tons of emissions)	496	71.839	62.100	45.254	0.075	200.300
SM (tons of emissions)	496	61.171	50.000	44.945	0.074	198.021
VOC (tons of emissions)	496	13.839	11.662	11.364	0.062	69.347
NH_X (tons of emissions)	496	1.042	0.835	0.951	0.000	5.687
SCALE (GDP in billion ¥'s)	496	1310.929	925.115	1296.560	18.450	7281.255
KL (thousand ¥'s/laborer)	496	33.838	30.775	18.324	8.299	111.390
INC (thousand ¥'s)	496	36.294	29.548	28.491	3.532	199.182
TI (% import + export/GDP)	496	32.475	13.774	39.724	3.799	171.107
REL.KL	496	1.000	0.871	0.519	0.305	3.219
REL.INC	496	1.000	0.909	0.282	0.685	2.127

Table 2 Unit root test

	1st generation panel unit root testing		2nd generation panel unit root testing	
	LLC	IPS	CIPS	Pescadf
SO_2	0.148 [0.558]	3.027 [0.998]	1.743 [0.959]	− 1.379 [0.959]
ΔSO_2	− 4.767*** [0.000]	− 1.653** [0.049]	− 3.201*** [0.001]	− 2.515*** [0.000]
SM	− 0.637 [0.262]	1.625 [0.948]	0.203 [0.581]	− 1.803 [0.336]
ΔSM	− 1.645* [0.072]	− 5.713*** [0.000]	− 3.735*** [0.000]	− 2.851*** [0.000]
VOC	− 0.277 [0.390]	2.397 [0.992]	1.438 [0.925]	− 1.963 [0.107]
ΔVOC	− 1.371* [0.085]	− 4.098*** [0.000]	− 3.916*** [0.000]	− 2.987*** [0.000]
NH_X	− 0.941 [0.169]	− 0.265 [0.395]	1.471 [0.929]	2.610 [1.000]
ΔNH_X	− 5.226*** [0.000]	− 2.119** [0.017]	− 2.138** [0.016]	− 2.139** [0.016]
SCALE	6.414 [1.000]	4.003 [1.000]	0.129 [0.551]	− 1.754 [0.431]
ΔSCALE	− 1.853** [0.049]	− 7.740*** [0.000]	− 3.337*** [0.000]	− 2.755*** [0.000]
KL	6.659 [1.000]	− 0.829 [0.203]	2.275 [0.989]	− 1.914 [0.160]
ΔKL	− 4.441*** [0.000]	− 2.750*** [0.003]	− 3.851*** [0.000]	− 2.965*** [0.000]
KL^2	1.255 [0.895]	0.326 [0.628]	2.130 [0.983]	−1.518 [0.849]
ΔKL^2	− 1.917** [0.027]	− 4.508*** [0.000]	− 4.698*** [0.000]	− 2.857*** [0.000]
INC	3.776 [0.999]	5.954 [1.000]	1.322 [0.907]	− 1.440 [0.924]
ΔINC	− 5.401*** [0.000]	− 3.957*** [0.000]	− 3.911*** [0.000]	− 2.682*** [0.000]
INC^2	3.776 [1.000]	0.537 [0.704]	2.593 [0.995]	−1.398 [0.950]
ΔINC^2	− 5.027*** [0.000]	− 5.661*** [0.000]	− 3.810*** [0.000]	− 2.573*** [0.000]
INC*KL	− 0.087 [0.465]	5.718 [1.000]	2.219 [0.987]	− 1.578 [0.765]
ΔINC*KL	− 2.420*** [0.008]	− 4.386*** [0.000]	− 3.923*** [0.000]	− 2.854*** [0.000]
TI	− 1.205 [0.114]	0.045 [0.518]	3.616*** [1.000]	− 1.012 [1.000]
Δ TI	− 2.689*** [0.004]	− 4.006*** [0.000]	− 3.813*** [0.000]	− 2.610*** [0.000]
TI*REL.KL	− 0.841 [0.200]	2.073 [0.980]	3.546 [1.000]	− 1.026 [1.000]
ΔTI*REL.KL	− 3.110*** [0.001]	− 5.848*** [0.000]	− 4.271*** [0.000]	− 2.654*** [0.000]
$TI*(REL.KL)^2$	− 0.916 [0.174]	2.695 [0.996]	3.159 [0.999]	−1.066 [1.000]
$\Delta TI*(REL.KL)^2$	− 5.848*** [0.000]	− 4.984*** [0.000]	− 4.181 [0.000]	− 2.901*** [0.000]
TI*REL.INC	− 0.497 [0.309]	0.205 [0.581]	3.032 [0.999]	− 0.874 [1.000]
ΔTI*REL.INC	− 2.911*** [0.003]	− 4.277*** [0.000]	− 4.319*** [0.000]	− 2.795*** [0.000]
$TI*(REL.INC)^2$	− 0.763 [0.223]	− 0.067 [0.473]	2.523 [0.994]	− 1.139 [0.998]
$\Delta TI*(REL.INC)^2$	− 5.993*** [0.000]	− 5.028*** [0.000]	− 4.292*** [0.000]	− 2.880*** [0.000]

Δ indicates the first-order difference; values in the brackets are the *p* values; the form of unit root test adopted in this paper is intercept plus trend; and *, **, and *** indicate significance at the 10%, 5%, and 1% levels

Table 3 The effects of trade and other core factors on the emissions of SO_2, SM, COD, and NH_X

	SO_2	SM	VOC	NH_X
SCALE	0.009*** (0.001)	0.019*** (0.002)	0.004*** (0.001)	0.001*** (0.001)
KL	0.545*** (0.111)	1.033*** (0.193)	0.101 (0.065)	0.019*** (0.006)
KL^2	− 0.002*** (0.001)	− 0.003*** (0.001)	− 0.001 (0.001)	− 0.001*** (0.001)
INC	− 1.061*** (0.345)	− 2.149*** (0.601)	0.581*** (0.203)	0.079*** (0.020)
INC^2	0.006*** (0.002)	0.011*** (0.004)	− 0.002* (0.001)	− 0.001*** (0.001)
INC*KL	0.006*** (0.002)	0.011*** (0.004)	−0.002* (0.001)	−0.001*** (0.001)
TI	− 0.720** (0.362)	− 0.013 (0.629)	− 0.462* (0.213)	− 0.056*** (0.021)
TI*REL.KL	0.071 (0.102)	0.412** (0.178)	0.072 (0.060)	0.012** (0.006)
$TI*(REL.KL)^2$	− 0.071 (0.102)	− 0.412** (0.178)	− 0.072 (0.060)	− 0.012** (0.006)
TI*REL.INC	− 0.168* (0.464)	− 0.246 (0.808)	− 0.603** (0.273)	− 0.078*** (0.026)
$TI*(REL.INC)^2$	0.273* (0.157)	0.053 (0.274)	0.162* (0.092)	0.023*** (0.009)
Time fixed	yes	yes	yes	yes
Province fixed	yes	yes	yes	yes
Observations	496	496	496	496
Provinces	31	31	31	31
R-squared	0.971	0.912	0.844	0.792

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; the values in parentheses are the standard deviations

(2001). They believed that the expansion of economic scale in a country led to excessive use of resources and degradation of environmental quality; thus, economic scale had a negative effect on environmental quality.

In terms of the coefficients of the capital-labor ratio, the impacts of KL on the emissions of the four pollutants are positive. The SO_2, SM, COD, and NH_X emissions significantly augment with the increase in the capital-labor ratio, which shows that when the growth of capital-intensive industries exceeds the growth of labor-intensive industries, the pollutant emissions increase accordingly. This result illustrates that the current industrial structure in China may aggravate the pollutant emissions. Compared with the impacts of KL, the impacts of KL^2 are very small, which indicates that the relationship between pollutant emissions and capital-labor ratio is nearly linear. This result is in accordance with that of Dean (2002), who believed that China's economic composition had negative effects on its environmental quality.

With regard to the coefficients of per capita income, the impacts of INC on SO_2 and SM emissions are negative, and the impacts of INC^2 on SO_2 and SM emissions are positive. This means that the influence of the quadratic term is strong and the relationship between the emissions of these two air pollutants and per capita income is not linear, but U-shaped, indicating that when per capita income is low, the environmental quality can be improved with the increase in per capita income, yet when per capita income increases to a certain degree, the environmental quality can be deteriorated as the per capita income increases. However, the impacts of INC and INC^2 on COD and NH_X emissions are opposite, which implies that the environmental Kuznets curves of these two water pollutants are inverted U-shaped, indicating that when per capita income is low, the environmental quality can be deteriorated with the growth of per capita income, yet when per capita income increases to a certain extent, the environmental quality can be improved along with the increase of per capita income.

The cross term of capital-labor ratio and per capita income INC*KL aims to test the impact of the interaction of economic composition (capital-labor ratio) and environmental regulation (per capita income) on pollutant emissions. The impacts of INC*KL on SO_2 and SM emissions are significantly positive, which shows that when the capital-labor ratio is high, per capita income increases the emissions of SO_2 and SM. However, the impacts of INC*KL on COD and NH_X emissions are significantly negative, which shows that when the capital-labor ratio is high, per capita income reduces the emissions of COD and NH_X.

With regard to the coefficients of trade openness, the estimation results of the four pollutants all indicate that during the sample period, trade openness has a positive effect on environmental quality and is statistically significant. Among the four pollutants, trade openness has the most positive effect on SO_2 emissions. This finding is opposite to that of Esty and Dua (1997) but accords with Hettige et al. (1992) and Jevan (2017). Esty and Dua (1997) believed that as a consequence of global trade liberalization, countries would lower their environmental quality standards for the purpose of maintaining and enhancing competitiveness, and the phenomena of "racing to the bottom" and "pollution haven" appeared. However, Hettige et al. (1992) and Jevan (2017) stated that compared with that of closed economic entities, the economic growth of the open economic entities had less negative influences on pollution; countries with faster GDP growth rate and trade liberalization enjoyed lower growth rates of pollution density; and there existed a negative correlation between trade liberalization and pollution density.

The estimation results of the cross term of trade openness and relative capital-labor ratio TI*REL.KL are all positive, which means that when the relative capital-labor ratio is low, trade openness intensively reduces the emissions of the four pollutants. This viewpoint is also supported by Cole and Elliot (2003), in their analysis of scale, technology, composition, and trade elasticities. The impacts of TI*(REL.KL)^2 are all negative, which implies that the marginal effect of the environmental destruction caused by the economic composition in relation to trade openness is decreasing.

The estimation results of the cross term of trade openness and relative per capita income TI*REL.INC are as follows: the impacts of TI*REL.INC on the four pollutants are negative, which means that when the relative per capita income is higher, trade openness reduces pollutant emissions more intensively. This result is in accordance with that of Fu and Zhou (2010), who believed that, on the one hand, the income growth caused by the trade development could further reinforce the strictness of the environmental regulation, whose effects would increase the cost of pollution and lead the transfer of consumption and production to clean industries; on the other hand, in the course of economic development, changes in demand structures would bring about changes in trade patterns. The impacts of TI*(REL.INC)^2 on four pollutants are positive, which shows that the marginal effect of environmental improvement caused by relative per capita income with respect to trade openness is decreasing.

Scale, composition, technique and trade elasticities

To further analyze the influences of economic scale, economic composition, technique level, and trade openness on the environment in China, this paper conducts elasticity analysis. The researchers bring the above 496 sample observations into Formula (1) for each pollutant, use the SUR method to make regressions, and obtain the regression coefficients of scale, KL, INC, and TI, that is, α_{g1}, α_{g2}, α_{g3}, and $\alpha_{g4}\Psi_g$. Then, they multiply these coefficients by the average value of trade openness $\bar{I}T$ and divide them by the average value of emissions of pollutant $\overline{Z}_g$ during the sample period. In this way, they obtain the scale, composition, technique, and trade elasticities of pollutant g, and these elasticities show the change in pollutant emissions caused by one unit change in economic scale, capital-labor ratio, per capita income, and trade openness, respectively, which are shown in Table 4. Table 4 shows that the scale elasticities and composition elasticities are positive, but the technique elasticities and trade elasticities are negative.

To further analyze the influences of economic scale, economic composition, technique level, and trade openness on environment under different levels of capital abundances and incomes, this paper conducts elasticity analysis on the basis of the sample observations whose relative capital-labor ratio and relative per capita income are less than or equal to 1 and the relative capital-labor ratio and relative per capita income are larger than 1.

Since there are 316 observations whose relative capital-labor ratios (REL.KL) are less than or equal to 1 and 180 observations whose relative capital-labor ratios (REL.KL) are larger than 1, this paper brings the above 316 sample observations and 180 sample observations into Formula (1) for each pollutant, uses the SUR method to make regressions, and then obtains the estimation results which are based on different relative capital-labor ratios and shown in Table 5.Meanwhile, they bring 352 sample observations whose relative per capita incomes (REL.INC) are less than or equal to 1 and 144 sample observations whose relative per capita incomes (REL.INC) are larger than 1, into Formula (1) for each pollutant, use the SUR method to make regressions, and obtain the estimation results based on different relative per capita incomes; then, they calculate the scale, composition, technique, and trade elasticities based on different relative per capita incomes, as shown in Table 5.

In terms of the observations whose relative capital-labor ratios and relative incomes are less than or equal to 1, the scale elasticities of the four pollutants are positive and larger than those of China, indicating that when relative capital-labor ratios and relative incomes are low, the negative influence of the expansion of economic scale on the environment will be more obvious, which is similar to the result of Cole et al. (2010). The composition elasticities are positive, which indicates that labor-intensive industries have more obvious comparative advantages in clean production than capital-intensive industries. The technique elasticities are negative, like those of China, indicating that the increase in income level stimulates the investment in environmental protection and the technique innovation and then improves the environmental situation. This finding is in accordance with that of Frankel and Rose (2005), who held that the increase in income has a significant negative influence on environmental pollution. The trade elasticities are negative, which are in accordance with those of China, indicating that trade openness directly promotes the environmental quality. The possible reasons for this are that the provinces with higher capital-labor ratios and incomes own more abundant capital and have the capacity to adopt the advanced foreign environmental management methods through trade and investment, and their environmental Kuznets curves are lower and flatter. This result is in

Table 4 Scale, composition, technique, and trade elasticities

	SO_2	SM	VOC	NH_X
Scale elasticity	0.170***	0.399***	0.336***	0.695***
Composition elasticity	0.097***	0.114***	0.018	0.225*
Technique elasticity	− 0.082*	− 0.052	− 0.579***	− 1.426***
Trade elasticity	− 0.064**	− 0.100*	− 0.245***	− 1.307***

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively

accordance with the finding of Muhammad and Faiz (2011), who believed that developing countries could develop their per capita GDP and upgrade their environmental quality from the lower and poorer status to higher and better status through trade. However, this result is different from that of Reeve et al. (1995), who questioned the positive effects of economic growth and environmental protection brought about by trade liberalization. He believed that trade growth neither effectively promoted social welfare nor benefited environmental protection. In addition, the destructive effect of trade liberalization was more obvious in developing countries.

With regard to the observations whose relative capital-labor ratios and relative incomes are larger than 1, the scale elasticities of the four pollutants are also positive, and all of them are smaller than those of China and those of the observations whose relative capital-labor ratios and relative incomes are less than or equal to 1. This illustrates that the expansion of economic scale leads to limited environmental deterioration in regions with high relative capital-labor ratios and relative incomes. The composition elasticities are negative but not significant, in contrast to those of the observations whose relative capital-labor ratios and relative incomes are less than or equal to 1. This shows that the industrial structure has a non-obvious impact on the environment in regions with low capital-labor ratios and incomes. The technique elasticities are negative and smaller than those of the observations with lower relative capital-labor ratios and relative incomes, showing that the positive technique effect in the regions with higher capital-labor ratios and incomes is larger than that in the regions with lower capital-labor ratios and relative incomes. The trade elasticities are negative, larger, and less significant than those in the regions with lower relative capital-labor ratios, which proves that trade openness in the regions with higher relative capital-labor ratios has a less positive influences on the environment. However, the trade elasticities are negative and smaller than those in the regions with lower relative incomes, which makes it clear that trade openness has a more positive influences on the environment in the regions with higher relative income.

Province-specific trade elasticities

To further analyze China's province-specific trade elasticities and the relationship between province-specific trade elasticities and capital abundance and relative income, the authors of this paper bring 496 sample observations into Formula (1) to establish 31 equations, use the SUR method to make regressions and obtain regression coefficients of TI of 31 provinces, and then calculate the province-specific trade elasticities, to show the change in pollutant emissions caused by one unit change in trade openness. The province-specific trade elasticities are shown in Table 6. It is clearly seen from Table 6 that among the 31 provinces, there are 25, 18, 20, and 24 provinces whose trade elasticities are negative for SO_2, SM, COD, and NH_X emissions, respectively, which means that trade openness has a positive influence on the environment in most provinces and a negative influence in only a few provinces in China.

Then the researchers of this paper draw the scatter figures representing the relationships between trade elasticities and relative capital abundance and relative income for SO_2, SM, COD, and NH_X in China's 31 provinces, as shown in Figs. 1 and 2. It is clearly seen from Fig. 1 that there are more negative trade elasticities in the provinces whose relative capital-labor ratios are less than or equal to 1. This is because the provinces with lower capital-labor ratios have comparative advantages in labor-intensive and less-contained industries, and trade openness promotes the decrease in pollutant emissions.

Table 5 Scale, composition, technique, and trade elasticities based on different relative capital-labor ratios and different relative per capita incomes

	SO_2	SM	VOC	NH_X	SO_2	SM	VOC	NH_X
REL.KL< = 1					REL.INC< = 1			
Scale elasticity	0.322***	0.512***	0.474***	0.573***	0.428***	0.480***	0.521***	0.655***
Composition elasticity	0.204***	0.622***	0.134*	0.175*	0.171***	0.322***	0.085	0.315***
Technique elasticity	− 0.164**	− 0.337**	− 0.347*	− 0.444*	− 0.196	− 0.915***	− 1.699***	− 1.721***
Trade elasticity	− 0.117***	− 0.157**	− 0.281***	− 0.411***	− 0.084***	− 0.068	− 0.204**	− 0.127**
Observations	316	316	316	316	352	352	352	352
REL.KL > 1					REL.INC > 1			
Scale elasticity	0.138***	0.363***	0.259***	0.483***	0.357***	0.233***	0.325***	0.184
Composition elasticity	0.035	− 0.140	− 0.097	− 0.151	− 0.052**	− 0.056	− 0.043*	− 0.065
Technique elasticity	− 0.446***	− 0.246	− 0.601***	− 0.604**	− 0.208***	− 0.269*	− 0.033	− 0.617*
Trade elasticity	− 0.101*	− 0.121**	− 0.184**	− 0.069	− 1.073	− 0.166	− 0.347***	− 0.371***
Observations	180	180	180	180	144	144	144	144

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively

Because of their rich population resources, these provinces have obvious comparative advantages in clean and labor-intensive industries. Therefore, their trade elasticities are negative. However, it can also be seen from Fig. 2 that there are more negative trade elasticities in the provinces whose relative per capita income is higher than 1. The reason for this is that the provinces with higher incomes have stricter environmental standards, which leads them to form their own comparative advantages in the clean industries, and then trade openness brings about the improvement of environmental quality. The results are in accordance with that in Table 3.

Most province-specific trade elasticities are almost 0, indicating that for most of China's provinces, the positive and negative effects that trade openness imposes on environmental pollution cancel each other out, so there seldom exists any relationship between trade openness and environmental pollution. A possible reason is that many Chinese provinces with low income have low capital-labor ratios, which leads the environmental regulation effects and resource endowment effects to cancel each other out. For example, in the provinces with low relative income, such as Yunnan and Guizhou, the low income entails less stringent demands for environmental quality. In addition, these are regions with clean and labor-intensive industries. However, in provinces with high relative income, such as Shanghai and Guangzhou, the high income leads to more stringent demands for environmental quality. These provinces are also regions with contaminated and capital-intensive industries. Therefore, the positive and negative environmental effects that these two factors bring about cancel each other out, which leads to the little effect of trade openness on environmental quality in most provinces.

In addition, as shown in Fig. 1, there exists an obvious divergence between the trade elasticities in the provinces whose relative capital-labor ratios are less than or equal to 1 and in the provinces whose relative capital-labor ratios are higher than 1. However, as shown in Fig. 2, there exists a more obvious divergence in the trade elasticities in the provinces whose relative incomes are higher than 1, than in those whose relative incomes are less than or equal to 1. In addition, Figs. 1 and 2 show that, compared with the air pollutants SO_2 and SM, the water pollutants VOC and NH_X present more obvious divergences in the trade elasticities. This result is in accordance with that of Cole and Elliott (2003), who believed that the influences of trade on air and water pollutant emissions were different.

Robustness analysis

2SLS for panel data

There may exist a reverse causal relationship between trade openness and pollutant emissions, or missing important explanatory variables may lead to the endogeneity problem, so the researchers employ the shortest distance among the distances from the provincial capital to Shanghai Port, Tianjin Port, and Hong Kong Port as the instrumental variable for trade openness and conduct 2SLS estimation. The results are shown in Table 7. It is clearly shown in Table 7 that all the F statistics in the first stage are greater than 10, rejecting the null

Table 6 Province-specific trade elasticities of SO_2, SM, VOC, and NH_X

Province	SO_2	SM	VOC	NH_X	Province	SO_2	SM	VOC	NH_X
Beijing	− 1.570*	0.498*	− 7.733**	− 8.240	Hubei	− 0.193	− 0.258*	− 0.001*	− 0.029*
Tianjin	− 1.380*	1.427	4.702	1.900	Hunan	− 0.037*	0.034	0.064	0.023
Hebei	0.001**	− 0.018	0.004*	0.007*	Guangdong	− 0.085*	0.278	0.499**	− 0.024**
Shanxi	0.001	− 0.015	0.006*	0.010	Guangxi	− 0.017	0.004*	− 0.028**	− 0.052
Neimenggu	− 0.018**	− 0.037*	− 0.065*	− 0.163*	Hainan	− 2.956	− 2.326	− 1.715	− 2.105
Liaoning	− 0.022**	0.044***	− 0.037*	0.170*	Chongqing	− 0.092***	− 0.081	− 0.282	− 0.259
Jilin	− 0.448*	− 0.554*	− 0.002*	− 0.168*	Sichuan	− 0.011**	0.003*	− 0.050**	− 0.075*
Heilongjiang	0.021	0.062	0.016*	− 0.291	Guizhou	− 0.062	− 0.092	− 0.002	− 0.137
Shanghai	0.480	0.927	− 8.208	− 6.027	Yunnan	− 0.167	− 0.113	− 0.071	− 0.467**
Jiangsu	− 0.067*	0.097	0.226	− 0.124*	Xizang	− 1.190*	− 0.879*	− 9.045	− 4.423
Zhejiang	0.102	0.204	0.454*	0.308	Shaanxi	− 0.020*	− 0.005*	− 0.028	− 0.066***
Anhui	0.002	− 0.053*	0.009	0.011	Gansu	− 0.048*	− 0.048	− 0.188**	− 0.130
Fujian	− 0.198**	− 0.199*	− 0.384	− 0.090**	Qinghai	− 0.123***	− 0.072***	− 0.117*	− 0.175***
Jiangxi	− 0.132	− 0.038	− 0.064	− 0.096	Ningxia	− 0.020	0.067	0.105	− 0.003
Shandong	− 0.045	− 0.042*	− 0.146	− 0.290	Xinjiang	− 0.152*	− 0.134*	− 0.177*	− 0.361**
Henan	− 0.006	0.009	0.024***	− 0.008					

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively

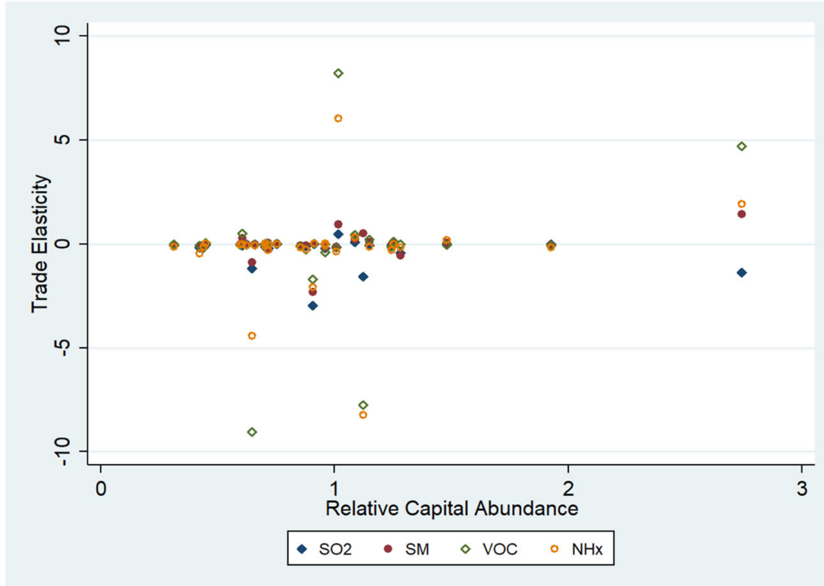

Fig. 1 Province-specific trade elasticities of SO_2, SM, VOC, and NH_X and relative capital abundance

hypothesis that weak instrumental variables exist, so the instrumental variable is exogenous. Moreover, the environmental effects of trade and other core factors in Table 7 are basically consistent with the above results in Table 3. However, compared with previous results, there are some differences in significance levels.

Counterfactual analysis of trade elasticity

Table 8 shows the province-specific trade elasticities and China's trade elasticity based on a 5% increase in trade openness for SO_2, SM, VOC, and NH_X. The absolute values of the trade elasticities of SO_2, SM, and VOC for 31 provinces and China are smaller than those in Table 6, but the absolute values of the trade elasticities of NH_X for 31 provinces and China are larger than those in Table 6. The result indicates that the increase in trade openness leads to less negative effects on emissions of SO_2, SM, and VOC, but more negative effects on emissions of NH_X for 31 provinces and China, and this result is consistent with that of Derek (2008). On the whole, there are negative effects of trade openness on pollutant emissions for most provinces in China, which is consistent with the above outcomes in Tables 4 and 6. In these results, a

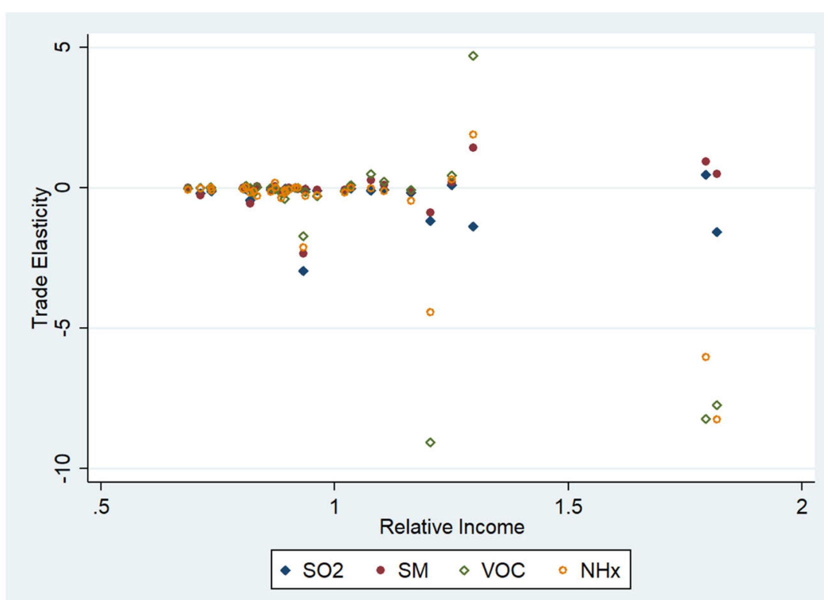

Fig. 2 Province-specific trade elasticities of SO_2, SM, VOC, and NH_X and relative income

Table 7 2SLS regression

	SO_2	SM	VOC	NH_X
SCALE	0.009***	0.022***	0.003**	0.001
	(0.002)	(0.003)	(0.001)	(0.001)
KL	0.583***	0.921***	0.246**	0.021*
	(0.166)	(0.287)	(0.109)	(0.012)
KL^2	− 0.003**	− 0.008***	− 0.002***	− 0.001***
	(0.001)	(0.002)	(0.001)	(0.001)
INC	− 0.760***	− 1.740***	− 0.146	− 0.013
	(0.220)	(0.381)	(0.144)	(0.015)
INC^2	0.003	0.003	0.002	0.001**
	(0.002)	(0.004)	(0.002)	(0.001)
INC*KL	0.004	0.017**	0.009***	0.001***
	(0.005)	(0.008)	(0.003)	(0.001)
TI	− 0.659*	− 2.438*	− 1.990***	− 0.266***
	(1.156)	(2.001)	(0.758)	(0.081)
TI*REL.KL	0.183	0.673***	0.032	0.004
	(0.132)	(0.228)	(0.086)	(0.009)
$TI*(REL.KL)^2$	− 0.046	− 0.144***	− 0.002	− 0.001
	(0.029)	(0.051)	(0.019)	(0.002)
TI*REL.INC	− 0.800	− 2.650	2.468**	0.323***
	(1.461)	(2.530)	(0.958)	(0.102)
$TI*(REL.INC)^2$	0.262	0.869	− 0.832***	− 0.106***
	(0.485)	(0.840)	(0.318)	(0.034)
Time fixed	yes	Yes	yes	yes
Province fixed	yes	Yes	yes	yes
F statistics	24.53	23.84	18.58	17.03
Observations	496	496	496	496
Provinces	31	31	31	31
R-squared	0.974	0.914	0.843	0.787

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; the values in parentheses are the standard deviations

difference in significance level is again observed here. The estimation results in this study are robust.

Conclusions and recommendations

Based on the empirical model of environmental effect of trade of Antweiler et al. (2001), this paper uses the SUR regression method and the panel data of the 31 provinces in China from 2000 to 2015 to analyze the impacts of trade openness on two main kinds of air pollutants, SO_2 and SM, and two main kinds of water pollutants, VOC and NH_X. The research findings are as follows.

First, China's deteriorating environmental quality is induced by the current economic scale and economic composition of the country. Additionally, per capita income and trade openness promote environmental quality. Trade openness reduces pollutant emissions more intensively when the relative capital-labor ratio is lower or the relative per capita income is higher. The implications are as follows: the positive effects of per capita income and trade openness on environmental quality imply that China can continue to improve the environmental quality through environmental regulation and trade liberalization, but the negative effects of economic scale and factor endowment on environmental quality mean that China should change the extensive economic growth mode and speed up industrial structure adjustment to avoid the deterioration of the environment.

Second, for the observations with lower relative capital-labor ratios and relative per capita incomes, the scale elasticities and composition elasticities of the four pollutants are significantly positive and larger than those of observations with higher relative capital-labor ratios and relative incomes; technique elasticities are negative and larger than those of observations with higher relative capital-labor ratios and relative per capita incomes; trade elasticities are negative and smaller than those in the regions with higher relative capital-labor ratios, but the

Table 8 Counterfactual analysis of trade elasticity

Region	SO_2	SM	VOC	NH_X	Region	SO_2	SM	VOC	NH_X
Beijing	− 0.107*	− 0.131*	− 1.919*	− 23.496*	Hubei	0.002**	0.002*	0.006**	0.054
Tianjin	− 0.011*	− 0.014*	− 0.082*	− 0.673*	Hunan	− 0.064*	− 0.074	− 0.239	− 1.781
Hebei	0.001**	0.001	0.006	0.074	Guangdong	−0.021*	−0.025*	−0.087*	− 1.835*
Shanxi	0.001	0.001	− 0.001*	− 0.016*	Guangxi	− 0.001*	− 0.001*	− 0.002	− 0.043*
Neimenggu	0.001**	0.001*	0.010*	0.134*	Hainan	− 0.011*	− 0.014	− 0.025*	− 0.456
Liaoning	− 0.002***	− 0.002***	− 0.012*	− 0.184*	Chongqing	− 0.001	− 0.002*	− 0.010	− 0.116**
Jilin	− 0.006*	− 0.006*	− 0.018	− 0.504	Sichuan	− 0.004*	− 0.004	− 0.016**	− 0.261
Heilongjiang	− 0.006	− 0.006*	− 0.023**	− 0.386**	Guizhou	− 0.001**	− 0.001**	− 0.027	− 0.419
Shanghai	− 0.041	− 0.047	− 0.485*	− 5.964*	Yunnan	− 0.005*	− 0.006	− 0.021	− 0.664*
Jiangsu	− 0.002	− 0.002	− 0.009*	− 0.132*	Xizang	− 0.310**	− 0.290**	− 0.950*	− 33.699*
Zhejiang	0.001	0.001	− 0.001	− 0.007*	Shaanxi	− 0.001**	− 0.001*	− 0.005	− 0.105***
Anhui	0.002**	0.002*	0.010*	0.084**	Gansu	0.001	0.001	0.006***	0.031*
Fujian	− 0.032	− 0.035	− 0.147**	− 1.785*	Qinghai	− 0.004*	− 0.004	− 0.015***	− 0.343***
Jiangxi	− 0.002	− 0.002	− 0.009*	− 0.115*	Ningxia	0.001	0.001	0.002	0.023
Shandong	− 0.009	− 0.012*	− 0.064	− 0.913	Xinjiang	− 0.033**	− 0.039*	− 0.127**	− 2.948**
Henan	− 0.001*	− 0.001*	− 0.003	− 0.027**	China	− 0.074**	− 0.115**	− 0.283***	− 1.836***

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively

trade elasticities are negative and larger than those in the regions with higher relative per capita incomes. The implications are as follows: regions with lower relative capital-labor ratios and relative per capita income can improve environmental quality more efficiently through economic scale and industrial structure adjustment, and regions with higher relative capital-labor ratios and relative per capita income can improve environmental quality more efficiently through per capita income and environmental regulation. Moreover, regions with lower relative capital-labor ratios can improve the environmental quality more efficiently through trade openness, but regions with higher per capita income can improve the environmental quality more efficiently through trade openness.

Finally, there exist 25, 18, 20, and 24 provinces among 31 provinces whose trade elasticities are negative, which means that trade openness has a positive influence on the environment in most provinces and a negative influence in only few provinces. There are more negative trade elasticities in the provinces whose relative capital-labor ratios are less than or equal to 1, but there are more negative trade elasticities in the provinces whose relative per capita income is higher than 1. Most of China's province-specific elasticities are almost 0, which indicates that for most provinces, the environmental regulation effect and resource endowment effect, both of which are imposed by trade openness on environmental pollution, cancel each other out. The implications are as follows: China should restrict the production and trade of pollution-intensive products by increasing income and environmental regulation and promote the development of clean and labor-intensive industries through industrial structural adjustment, to continuously make its trade developed towards low pollution.

Appendix

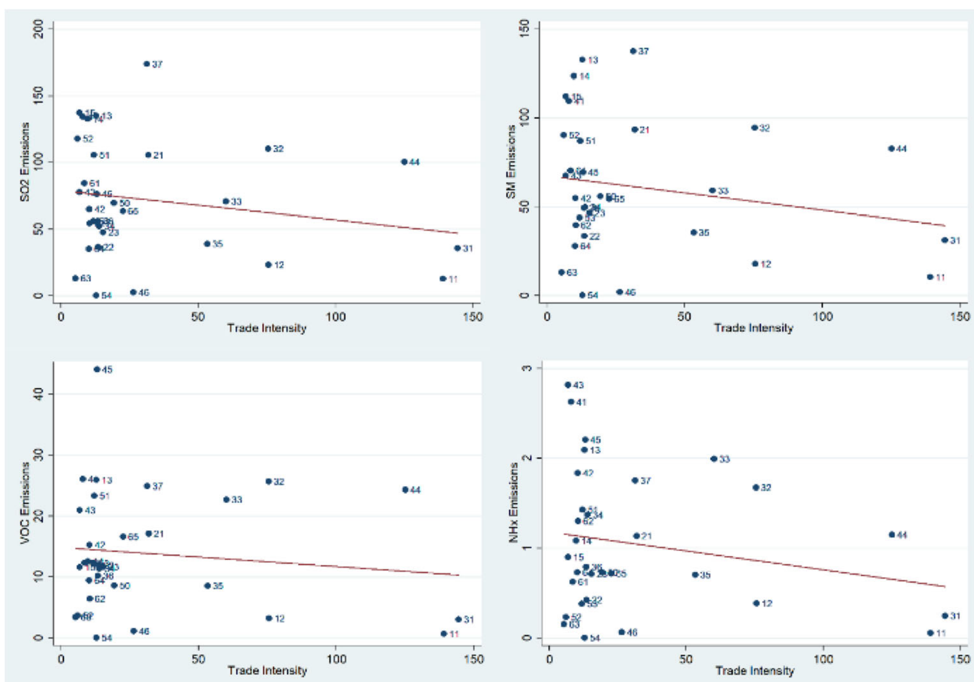

Fig. 3 Trade openness and emissions of SO_2, SM, COD, and NH_X

Table 9 Province list

Province name	Province code	Province name	Province code	Province name	Province code
Beijing	11	Anhui	34	Sichuan	51
Tianjin	12	Fujian	35	Xizang	52
Hebei	13	Jiangxi	36	Guizhou	53
Shanxi	14	Shandong	37	Yunnan	54
Neimenggu	15	Henan	41	Shaanxi	61
Liaoning	21	Hubei	42	Gansu	62
Jilin	22	Hunan	43	Qinghai	63
Heilongjiang	23	Guangdong	44	Ningxia	64
Shanghai	31	Guangxi	45	Xinjiang	65
Jiangsu	32	Hainan	46		
Zhejiang	33	Chongqing	50		

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