

The Empirical Analysis on Environmental Effects Caused by China Foreign Trade

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Abstract: Since reform and opening up, as an important factor of economic growth, trade has promoted the development of China's economy sharply, at the same time, it brought about the destruction of the ecological environment which is the focus of academic debate. There is still not any definite conclusion about the impact of trade on the environment. In this paper, by establishing a measurement model, we calculate the environmental effects of trade from scale, technology and structure three aspects, conclusion shows that the structure effect and technology effect of liberalization of trade will improve the level of China's environment, but the scale effect of trade while promoting economic expansion will cause environmental damage.

Key words: Foreign trade; Environmental effects; Scale effect; Technology effect; Structural effect

Since the reform and opening up, China creates an economic growth miracle, but meanwhile, China faces the increasingly serious environmental problems. Water pollution, air pollution and other environmental problems bring with industrialization becoming the bottleneck of social and economic development. And as tradition and FDI promoting economic development, whether they generating and increasing environment pollution has become the focus of academic debate. Environmentalists criticized that, China's export trade and absorbed FDI mostly in pollution-intensive industries, behind China's foreign trade volume increased, there is environmental costs which China borne for trading partners. But trade supporters consider that, trade can promote improvement of environment in long term. Evaluate trade environmental effects can not only simple examine the utility of trade volume growth on environment, it is essential to examine environmental effects of trade comprehensively from multiple perspective as size, technology and structure.

1 Introduction

Since 1970s, environment problem increasingly get attention, there is a lot of foreign literature studies the relationship between international trade and environment. Research focuses on environmental policies effect on export trade. There are specific research on environmental polices on trade method, trade term, and international competitiveness; since 90s of the 20 century, scope of study is wider, including trade liberalization effect on environment, north-south trade effect on environment, trade scale, the trade structure, trade methods effect on environment, trade policy and environmental policy coordination problems, economic methods which solve global environment problem, and "free-rider" problem in global environmental governance.

On the impact of trade liberalization on the environment, in current academia two diametrically opposed to point of view have been formed: environmentalists consider trade liberalization directly lead to the deterioration of the environment, especially in developing countries whose environment policy is loose. On this view is Chilchilnisky (1994), Daly (1993). On the other side, free trade supporters consider that, even though free trade can bring certain environmental damage, but they consider the reason why environmental damage occur mainly is market failure, so should not improve environment through restrict trade. They also consider trade can generate pollution in certain degree in short term, but only when tradition develop to certain stage, trade liberalization effect on the improvement of the environment (rational use of resources, specialization, technology improvement) will bigger than pollution effect of trade Bhagwati (1993), Grossman and Krueger (1991, 1993), Anderson and Blackhurst (1992) hold that view.

In empirical study, mainly focus on validate the following three problems: first is whether trade leads developing countries to become pollution paradise. Low and Yeats (1992), Lucas and Wheeler (1992), Hettige (1992), Beghin and Potier (1997), WDean (2004), Busse (2004), Feng Helen Liang (2005); second is trade and pollution whether in "pour u-shaped curve" relationship, Such as Grossman and Krueger (1991), Bhagwati (1993), Grossman and Krueger (1991, 1993, 1995), Lopez (1994),

Stern(1996). Third is whether countries compete to reduce environment standard in order to protect the national product, such as Easy and Geradin (1997), Dua and Esty (1997), Ropker(1994). Whatever which kind of hypothesis, have not been got consistency point of view in academia. Haisheng Mei (2005) use China's panel data and conclude that trade will deteriorate the environment. Xi Du and ling Liu (2006) consider trade has small effect on environment. Hongyan Guo and Liyan Han (2008) consider environmental Kuznets hypothesis is not established in China. Shunwu Huang and Yanxin Shi (2010) consider trade can make developed countries environment improve but increase developing countries, especially emerging countries environmental pollution.

The analysis Grossman and Krueger (1991) do when they analysis the effect of the signing of NAFTA on environment, initiate Trade-Environment General Equilibrium Analysis. Grossman and Krueger consider that the impact of trade liberalization on environment can be divided into three aspects: scale effects, composition effects and technological effects. Antweiler, Copeland and Taylor (2001) build a specific model to subdivide the three effects. Ru Jie (2006) considers foreign trade is motive mechanism of technology progressing and industrial upgrading. Yijun Yuan and Kun Dong (2008) think trade can bring structure optimization, and one of structure optimization demand is control pollution in a reasonable level. Shuijun Peng and Anping Liu (2010) consider the comprehensive effect of China's foreign trade on environment is negative, and since China participate in WTO in 2002, export expand rapidly, make the export structure optimization can't catch up with import structure adjustment, the proportion of pollution-intensive products increase in export, the price of trade surplus is pollution surplus. Lianzhong Zhang and Tan Zhu (2003), Tian Lan(2004) use national cross-section data or panel data and get conclusion: scale effects pollute environment, but technological effects and composition effects improve environment. Beidi Yu (2008) get further conclusion: negative scale effects in trade is over positive composition effects and technological effects, then trade increase environment pollution. Besides, some scholars add energy into model, consider that pollution emission and the type of energy used are in a great relationship, they further decompose technological effects into intensity of energy use and intensity of energy use per unit of output. Such as Hongmin Cheng(2009) further decompose technological effects into technological effect of energy utilization and technological effect of intermediate input. Empirical shows that, from 1992 to2002, export increase causes implied energy export increase, but in 1992 to 1997, technological effects promote implied energy export increase, it is contrary in 1997 to 2002, technological effects may reduce implied energy export, need to be guided. Kun Luo (2010) consider that scale effects and composition effects of China's import and export of pollution-intensive products are negative, but because of technological effects is positive, so net effects can be positive. Because distortion exists in factor price, make composition effects negative, and restrict the positive effect of technological effects.

2 Model

We make use of the model founded by Werner Antweiler, Brian R. Copeland and M. Scott Taylor(2001)¹.

Assumption 1: We assume that homeland is a small open countries, with population N , and two primary factors, that labor L and capital K . Homeland and the world both have two industries, cleaning industry x_1 and pollution-intensive industry x_2 , cleaning industry doesn't pollute and pollution-intensive industry generates pollution as a by-product. Homeland exports pollution-intensive products.

Assumption 2: the production technology for x_1 and x_2 can be described by unit cost functions $c_1(w, r)$ and $c_2(w, r)$, where w and r denote salary and Interest rates.

Assumption 3: We assume constant returns to scale, standard zero profit and full employment.

Let x_1 be the numeraire, and denote the relative price of x_2 by p . Since existing trade barriers, domestic prices will not be identical to world prices, we write $p = \beta p^w$. Where β measures the importance of trade frictions and p^w is the common world relative price. The more β

¹Read Werner Antweiler, Brian R. Copeland, M. Scott Taylor. *Is Free Trade Good for the Environment* [J], The American Economic Review, Vol.91, No.4, pp. 877-908.

close to 1, the more homeland open. It means there is no trade barriers, while $\beta=1$.

Denote pollution emissions by z , Pollution is generated by x_2 production. Firms have access to an abatement technology.

$$z = e(\theta)x_2 \tag{1}$$

Where $e(\theta)$ is emissions per unit of x_2 produced and is decreasing in θ , we assume $e'(\theta) < 0$, $e''(\theta) > 0$. If a firm allocates x_{2a} per unit x_2 to abatement, then $\theta = x_{2a}/x_2$.

The government uses pollution emission taxes to reduce pollution. Given the pollution tax t , the profits of pollution-intensive industry can be denote as:

$$\pi_2 = p^N x_2 - wL_2 - rK_2 \tag{2}$$

And net producer price for gross output is:

$$p^N = p(1 - \theta) - te(\theta) \tag{3}$$

Because of constant returns, the first order condition for the choice of implies:

$$p = -te'(\theta) \tag{4}$$

Hence $\theta = \theta(t/p)$, and then emissions per unit output is:

$$e = e(t/p) \tag{5}$$

The standard zero profit and full employment conditions can be denoted as:

$$1 = c_1(w, r) = c_1^L w + c_1^K r, p^N = c_2(w, r) = c_2^L w + c_2^K r \tag{6}$$

$$K = c_1^K x_1 + c_2^K x_2, L = c_1^L x_1 + c_2^L x_2 \tag{7}$$

Where c_i^j is the quantity of factor j needed for producing per unit output of x_i , $i = 1, 2, j = K, L$.

We write the indirect utility function of a consumer as:²

$$v(I, z) = U(I) - \delta z = U\left(\frac{G/N}{\rho(p)}\right) - \delta z$$

Where G is national income, $\rho(p)$ is a price index, so $I = \frac{G/N}{\rho(p)}$ is real per capita income,

and U is increasing and concave. Overall national income is private sector revenue plus rebated taxes, so, $G = R(p^N, K, L) + tz$, while private sector revenue is $R(p^N, K, L)$, t is pollution tax rate.

We assume the government chooses a pollution tax to maximize the sum utility of every computer, for we assume that all consumers have the same utility function, the government just need to maximize the utility of every computer. It solves

$$\max_t N * v = N * (\max v)$$

The first order condition yields

$$U'(I) \frac{dI}{dt} - \delta \frac{dz}{dt} = 0 \tag{8}$$

Then we have:

$$\frac{dI}{dt} = \frac{1}{N\rho(p)} \left(-\frac{dR}{dp^N} * \frac{dp^N}{t} + z + t \frac{dz}{dt} \right) = \frac{t}{N\rho(p)} \frac{dz}{dt} \tag{9}$$

Rearranging our first order condition as:

$$t(p, I) = N\delta\rho(p)U'(I) \tag{10}$$

With careful observation (1), we have

² We assume that all consumers have the same utility function.

$$\begin{aligned}
 z &= ex_2 = (e/p) * (px_2) \\
 &= (e/p) * \left(\frac{px_2}{px_2 + x_1}\right) * (px_2 + x_1) \\
 &= \varepsilon * \varphi * S
 \end{aligned}
 \tag{11}$$

Where $\varepsilon = (e/p)$ means the polluting emissions of per unit of output of x_2 , which is the mirror of abatement technology, $\varphi = \frac{px_2}{px_2 + x_1}$ is the share of pollution-intensive industry, and

$S = px_2 + x_1$ is the economic scale.

Differentiate (11), then we get

$$\hat{z} = \pi_1 \hat{\varepsilon} + \pi_2 \hat{\varphi} + \pi_3 \hat{S}
 \tag{12}$$

Where “^” denotes percent change, the first term the right side of (12) is the technical effect, scale effect, the second composition effect, and the third scale effect. From (12) we know pollution depends on the pollution intensity of the dirty industry, $e(\theta)$, the relative importance of the dirty industry in the economy, φ , and the overall scale of the economy, S , it means that we have only three paths to increase or decrease the emissions, that can change the scale, composition or technology.

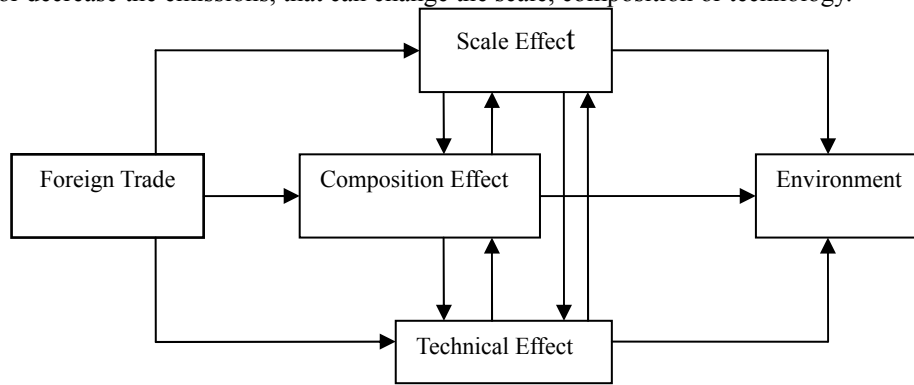


Figure 1 The Paths by Which Trade Change the Environment

(1) Technical Effect($\hat{\varepsilon}$)

From (5) and (10), we get

$$\varepsilon = e/p = e(t, p)/p = \varepsilon(t, p),$$

For $p = \beta p^w$ and $t = t(p, I)$, so

$$\varepsilon = \varepsilon(\beta, I)
 \tag{13}$$

(2) Composition Effect($\hat{\varphi}$)

The production of both the two industries depend on (6) and (7). Using the two equations of (7), we get the ratio of two factors,

$$\frac{K}{L} = \frac{c_1^K x_1 + c_2^K x_2}{c_1^L x_1 + c_2^L x_2}$$

Then we get relative output

$$\frac{x_2}{x_1} = \frac{kc_1^L - c_1^K}{c_2^K - kc_2^L}$$

Where $K/L = k$. For c_i^j is determined by the relative price of factors, (r/w) , which is depend on factor ratio k , x_2/x_1 is only related with k .

So,

$$\varphi = \frac{px_2}{px_2 + x_1} = \frac{\beta p^w x_2}{\beta p^w x_2 + x_1} = 1 - \frac{1}{\beta p^w \frac{x_2}{x_1} + 1} \tag{14a}$$

Rewrite (14a),

$$\varphi = \varphi(\beta, k) \tag{14}$$

(3)Scale Effect (\hat{S})

Using (7), we can solve for outputs,

$$x_1 = \frac{c_2^L K - c_2^K L}{c_1^K c_2^L - c_2^K c_1^L}, \quad x_2 = \frac{c_1^L K - c_1^K L}{c_1^L c_2^K - c_1^K c_2^L}$$

Similarly, we get $x_i = x_i(k, p)$, and rewrite the economic scale as:

$$S = px_2 + x_1 = S(k, p) = S(\beta, p) \tag{15}$$

We put forward the following propositions with strict proof.

Proposition 1: For a country exporting, pollution-intensive products, composition effect is positive.

Foreign trade will increase the share of x_2 and will pollute the environment.

For trade liberalization will raise the price of x_2 , with β larger and more close to 1. From (14a), we know β will make φ become larger.

Proposition 2: For a country exporting pollution-intensive product, scale effect is positive.

Holding constant the mix of goods produced, φ , and production techniques, $e(\theta)$, the economy are simply scaled up, trade liberalization, will increase the output of x_2 visibly, and destroy the environment.

Proposition 3: Technical effect can be positive and negative.

Trade liberalization will enlarge the scale, S, and raise the relative price of x_2 , p . The economic scale being larger will increase the income of consumer who will require for more cleaner environment, and the government will increase pollution tax rate, t . The companies may increase or decrease the investment on pollution reduction, θ , while both relative price p and pollution tax rate t increasing.

3 The Empirical Analysis

3.1 Modeling, variable selection and data description

According to equation (12), we can establish the following linear model:

$$z_t = a_{41} + a_{42}\varepsilon_t + a_{43}\varphi_t + a_{44}S_t \tag{16}$$

Since technical change in the environment and by (13) and (14), according to second-order Taylor expansion, respectively,

$$\varepsilon_t = a_{11} + a_{12}\beta_t + a_{13}\beta_t^2 + a_{41}I_t + a_{15}I_t^2 + a_{16}\beta_t I_t \tag{17}$$

$$\varphi_t = a_{21} + a_{22}\beta_t + a_{23}\beta_t^2 + a_{24}k_t + a_{25}k_t^2 + a_{26}\beta_t k_t \tag{18}$$

Equation (17) and (18) are the technical effects, structural effects.

During the inspection of the relationship between environment and economy, we often use pollution concentration or polluting emissions to measure the quality of the environment. Selected pollutants must meet two principles: first, select the emission of pollutants which associated with economic development is the discharge of pollutants during the economic development; second, the emission of pollutants have negative impact on economic development or the survival of human, otherwise there is no research significance. Industrial sulfur dioxide (SO_2) is main emissions bring by industrial production, and sulfur dioxide, which is an important cause of human respiratory diseases and a major source of acid rain, have greater harm on human life. For the above analysis, we use the sulfur dioxide emissions (SO_2). And high-polluting industries used to calculate ε_t and φ_t refer to industries

with high industrial SO_2 emissions. The selected data are based on "China Statistical Yearbook 2010" which divides by industry output per million of sulfur dioxide emissions up to ten Industry, which accounts for the more than 90% of the industrial SO_2 emissions. Higher SO_2 emissions per unit output industry. The variables used in this paper and their calculation methods and meanings as in Table 1.

The data of industrial emissions in this chapter are from various years of "National Environment Statistical Bulletin", "China Statistical Yearbook" and "Compendium of Environment Statistics of China (1981-1990)." The output value of high-polluting industries is from various years of "China Industrial Economy Yearbook" (the data of 2004 from the "Yearbook of the First National Economic Census".) And variable data required for other variables from various years of "China Statistical Yearbook." All the data related to prices are converted to 1985 constant prices to eliminate price factors. All data use the form of logarithm to reduce the disturbance of the heteroscedasticity. We use Eviews 5.0 software to calculate.

Table 1 Selection of Variables in the Empirical Part of This Paper

Variable	Unit	Name	Method of calculation
ε_t	ton/10000RMB	pollution emissions of high pollution industry unit output, reflecting the pollution level of technology	the ratio of emissions of SO_2 and unit output of industry with high emissions of SO_2
β_t	%	foreign trade dependence, reflecting the opening level of trade	the ratio of total import and export volume and GDP
I_t	RMB/person	per capita income, this article uses the per capita GDP	the ratio of the current year GDP and population
φ_t	%	high pollution industry in proportion of the GDP, to reflect the situation of the industrial structure	the ratio of value of industry with high emissions of SO_2 and GDP
k_t	RMB/person	the ratio of capital and labor, reflecting native endowments	the ratio of fixed assets investment and the total population
S_t	100 million RMB	economic scale	The current year GDP
z_t	10000 ton	emissions of SO_2	industrial emissions of the current year

3.2 Stationarity test

All variables are stationary or single whole is sufficient condition for a co-integration relationship between variables, otherwise may cause false return. Therefore, before the cointegration test we firstly must be implementing stationarity test to variables. Stability inspection is often used to unit root test. This paper uses ADF test method. The stability of the variables results in table 2. From table 2 we can see, all variables are first order sheet, there may have cointegration relationship between variables.

Table 2 Unit Root Test Results

Variables	Inspection type(c,t,k)	ADF value	The critical level of 5%	Conclusion
ε_t	(c,t,2)	-0.0823	-3.6122	non-stationary
$\Delta \varepsilon_t$	(c,0,1)	-3.4255	-2.9981	stationary
β_t	(c,t,0)	-2.0017	-3.6220	non-stationary
$\Delta \beta_t$	(c,0,0)	-3.3934	-2.9981	stationary
I_t	(c,t,1)	-2.7116	-3.6220	non-stationary
ΔI_t	(c,0,3)	-2.8131	-2.6422*	stationary
φ_t	(c,t,1)	-1.5659	-3.6220	non-stationary
$\Delta \varphi_t$	(c,0,3)	-3.0287	-2.9981	stationary
k_t	(c,t,1)	-2.2408	-3.6220	non-stationary
Δk_t	(c,0,3)	-2.8730	-2.6431*	stationary

S_t	(c,t,2)	-2.6222	-3.6220	non-stationary
ΔS_t	(c,0,3)	-2.8970	-2.6422*	stationary
z_t	(c,t,1)	-3.1502	-3.6220	non-stationary
Δz_t	(c,0,3)	-3.5117	-3.0124	stationary

Note: ① Δ means one order difference of variable; ②in the ADF test form (c, t, k), c for constant items, t is tendency item, k as lag order number, the selection criteria of k is AIC criterion. Mark * indicates 10% of the significant level down through stationarity test.

3.3 The cointegration analysis

This article uses the E-G two-step method for cointegration test. The so-called E-G two-step method is that firstly hypothesis there have cointegration relationship between variables, estimate coefficient of equation the equation, and then take the stationarity test for the residuals of equation. If residual can be smooth then variables have cointegration relationship. First of all, we estimate equation(16), (17) and (18). The results are in table 3.

Table 3 OLS Estimates Results

Coefficient	Equation(16)	Equation(17)	Equation(18)
Constant term α_{i1}	-4.8470*** (69.6365)	-20.4734*** (-6.8055)	8.8477*** (3.9669)
α_{i2}	1.0175*** (228.6684)	-4.7634*** (-3.0676)	0.3856*** (2.3757)
α_{i3}	1.0183*** (228.6684)	not significant	not significant
α_{i4}	1.0191*** (198.0412)	8.1446*** (8.3400)	-2.1056*** (-3.0288)
α_{i5}	-1.8462*** (-3.4043)	0.7082*** (-7.7366)	0.1631*** (3.3074)
α_{i6}	1.7267*** (2.4156)	0.5492*** (2.8260)	not significant
	AR(5) 0.8114*** (4.8804)	—	AR(1) 0.5388*** (2.1601)
<i>DW</i> statistic	2.0946	1.7092	1.6313
R^2	0.9999	0.9865	0.9614
$AD.R^2$	0.9999	0.9838	0.9523
<i>F</i> statistic	126495.5	365.8220	105.8661

Note: the number in the bracket is t statistic level of the estimation of corresponding coefficient. ***, **, * are respectively the significance level of 1%, 5% and 10%. Standard "not significant" means the coefficient of variables in the OLS estimates are not significant, so we will eliminate them to estimate again.

We can be seen from table 3 each equation all through the F inspection. The whole equation is significant. Making unit root test to the residual series of equation, and the specific results can be seen in table 4. We can see the residual of equation are zero order single sharp, ruled out false return. Therefore, we can consider that the explanation variables and be explained variables of each equation have cointegration relationship.

Table 4 Residual Inspection Result

Equation	Inspection type(c,t,k)	ADF value	The critical level of 5%	Conclusion
Equation(16)	(0,0,0)	-4.9173	-1.9602	stationary
Equation(17)	(0,0,0)	-4.2807	-1.9564	stationary
Equation(18)	(0,0,1)	-4.0852	-1.9556	stationary

3.4 The result analysis

Equation (16) reflects the size of the three kinds of effect that trade makes to opening up. From the estimated results we can see the coefficient of S_t , ε_t and φ_t are close to 1.02. The scale of economy increases every 1%, the emissions of SO₂ will be increased by 1.02%. The drainage technology improve

1% or pollution intensive dropped 1%, and the emissions of SO₂ will be reduced by 1.02%. Calculation under the same price in 1985, from 1985 to 2009 years, economy expanded about 9.54 times, pollution emissions technology has increased nearly 10 times (the pollution emission of unit output is about 1/10 of 1985). But total pollution industry also enlarged 2 times. The damage made by the scale effect to the environment offsets the improvement of technology effect to the environment, therefore, China's emissions of SO₂ has expanded for about 2 times compared to 1985.

Equation (17) reflects the technology effect made by opening trade to the environment. The coefficient of β_t is 4.7634. Trade openness each increased 1%, the emissions of per unit of output of pollution intensive industry will be reduced by 4.76%. The trade has great stimulative effect to technical and environmental provide. In addition, the per capita GDP also have great influence on pollution level. The coefficient of I and I^2 , that is α_{i4} and α_{i5} , were 8.1446 and 0.7082. Environmental technology level and I have a U curve relationship, which means that there exists inflexion point. When $I > 0.043$ (that is per capita GDP more than 11500 RMB), per capita GDP will increase the emissions of SO₂. In 2009, China's per capita GDP calculated with 1985's constant prices is about 6313 RMB, which is far less than 11500 RMB. This shows that the growth of China's per capita GDP helps to the improvement of the environment.

Equation (18) reflects the structure effect. The coefficient of β_t is 0.3856. Trade openness each increased 1%, GDP of pollution industry will increase 0.39%. China's foreign trade development structure is the increasing proportion of the pollution-intensive industries. And the industrial structure φ_t and the average fixed assets investment k_t has poured U curve relationship, there is a turning point ($k_t = 10900$ RMB / person). When k_t is more than 10900 RMB/person, the increase of capital compared to labor will force the proportion of polluting industries to decline. But in 2009 the average Chinese investment in fixed assets is only 4200 RMB, which have not achieved inflection point. China should continue to increase investment to fixed assets per capita and reach inflection point value as soon as possible. Opening trade did not bring the improvement of structure. The improvement of the environment which is made by trade through improving environmental technology level far outweighs the pollution brought about by the structure deterioration.

4 Conclusion and Advice for Further Research

This paper tries to analysis scale effects, composition effects and technological effects independently. From analysis result can see, development of trade can promote level of environment technology, but scale effects and composition effects deteriorate environment. Level of environment technology and GDP per capita are in U-shaped relationship, industrial structure φ_t and fixed asset investment per capita are in inverted U-shaped relationship, currently, GDP per capita and fixed asset investment per capita are not meet the inflection point.

This work is only a preliminary exploration, there are many areas for improvement. Firstly, this paper does not take reaction of environment and environment polices on trade and economic into account, the estimate of model has a certain bias; secondly, because this paper only selected SO₂ emissions as indicator of environment pollution level, not yet fully reflect the impact of trade on environment. So in future research, we can make environment pollution (including atmospheric environment, water environment, land, and so on) loss monetization through study, then compare with the benefits of trade, this can be fully reflect the environment damage caused by trade; thirdly, this paper only consider the environment pollution caused by export country production, neglect of pollution problems caused by transport, import, consumption, etc. we can try to put these factors into model.

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