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Environmental Effects of Foreign Trade and Its Spatial Variations in Mid-eastern Provinces and Cities of China

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Abstract: The studies on environmental effects of foreign trade and its spatial variations are helpful to design and implement environmental protection countermeasures. In order to eliminate the adverse effects of insufficient observation values on the accuracy of regression results and dynamic information quantity of fitting equation during empirical study, panel data of the mid-eastern provinces and cities of China from 1985 to 2007 were selected based on the adjustment of classical regression model in this paper. Panel unit root test and panel cointegration analysis method were applied to investigating the environmental effects of foreign trade and its spatial variations in the mid-eastern provinces and cities of China and its three groups divided by foreign trade dependence. The results show that all scale effects are positive, while all technical effects are negative and unable to counteract positive scale effects. Foreign trade development is regarded as an important cause for outstanding eco-environmental problems in the mid-eastern provinces and cities of China. Total effects and structural effects are significantly different among different groups because of spatial variations in environmental policies, export destinations, source of FDI, *etc*. Following the principle of ′coordinating generality and considering differences comprehensively′, it is essential to issue a series of policies and countermeasures corresponding to differences in regional environmental effect of foreign trade, in order to coordinate the relationship between foreign trade development and eco-environment in each region.
Keywords: mid-eastern provinces and cities of China; foreign trade; environmental effect; spatial variation; cointegration analysis

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1 Introduction

In 1993, environmental effect was decomposed into scale effect, structural effect and technical effect by Grossman and Krueger (Grossman and Krueger, 1993). Then, empirical researches on environmental effect of foreign trade were mainly conducted under this frame (Lee and Roland, 1993; Antweiler *et al.*, 2001; Dean, 2002), as applying Computable General Equilibrium Model (CGE) and regression models created by Antweiler *et al.* (2001). Judging from the results of empirical researches, scale effect is usually positive, i.e., scale expansion of economic activity induced by foreign trade development will lead to an increase in natural resource consumption and environmental pollution. Meanwhile, structural effect is either positive or negative, i.e., specialized division of labor induced by foreign trade development will result in the compatibility between industrial structure and comparable advantage, which might be beneficial to environment or not. Technical scale is usually negative, i.e., technology spillover through foreign trade development including foreign direct investment (FDI) will promote local productive efficiency and clean production, so as to reduce resource

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consumption and environment damage produced by each unit. Judging from empirical objects, present researches mainly focus on trade partners or individual region (Grossman and Krueger, 1993; Shen and Ren, 2006; Xu and Jin, 2009). However, few researchers pay attention to the difference of environmental effects of foreign trade among different regions in the same country, which are just the important basis for designing and classifying environmental protection policies and industrial policies. As viewed from the data applied in empirical researches, no matter time-series data (about 20 observed values) or cross-sectional data (about 30 observed values) based on insufficient samples (Zhang *et al.*, 2003; Li and Zhang, 2004; Zhang, 2006) may militate against the accuracy of regression results and dynamic information quantity of fitting equation significantly. As viewed from policy enlightenment, countermeasures and proposals are mainly designed for the whole country or a large area without further analyses on differences among middle-small regions, which may cause inapplicability of countermeasures or recommendations to specific region or even opposing effect.

For above reasons, using classical regression model as a basis, provincial panel data as samples and wastewater discharge as environmental effect index, the cointegration analysis method for panel data was applied herein to conducting empirical researches on environmental effects of foreign trade and its spatial variations in the mid-eastern provinces and cities of China. It was expected to increase domestic empirical research methods as well as provide a basis for formulating different eco-environmental protection policies in the mid-eastern provinces and cities of China.

2 Materials and Methods

2.1 Study area

The mid-eastern provinces and cities of China, including Heilongjiang, Jilin, Liaoning, Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan, are considered as China's economically-developed regions with a population of 6.31×10^8 (47.75% of the national total) and a land area of 1.94×10^8 km^2 (20.19% of the national total) (National Bureau of Statistics of China, 1986–2008). Export-oriented development strategy has been implemented universally in the major provinces and cities of this area, whose foreign trade dependence is more than 35% except Heilongjiang, Jilin, Hebei and Guangxi (Fig.1a). Foreign trade has been the important driving force for their fast economic development. From 1990 to 2007, total value of imports and exports of the study area was increased by 19.29% per annum, the total export was increased by 18.65% per annum, foreign trade dependence rose from 34.2% to 79.3%, and the annual contribution rate of export to gross domestic product (GDP) was 47.26% (National Bureau of Statistics of China, 1986–2008).

However, eco-environmental problems are outstanding with the fast development of foreign trade and economy. In 2007, 1.58×10^{10} t of waste water, 2.18×10^9 m^3 of waste gas and 8.1×10^8 t of solid wastes were discharged in this area, accounting for 64.2%, 56.05% and 46.3% in national total respectively (Beijing Municipal Bureau of Statistics, 1986–2008; Fujian Provincial Bureau of Statistics, 1986–2008; Guangdong Provincial Bureau of Statistics, 1986–2008; Guangxi Provincial Bureau of Statistics, 1986–2008; Hainan Provincial Bureau of Statistics, 1986–2008; Hebei Provincial Bureau of Statistics, 1986–2008; Heilongjiang Provincial Bureau of Statistics, 1986–2008; Jilin Provincial Bureau of Statistics, 1986–2008; Jiangsu Provincial Bureau of Statistics, 1986–2008; Liaoning Provincial Bureau of Statistics, 1986–2008; Shandong Provincial Bureau of Statistics, 1986–2008; Shanghai Municipal Bureau of Statistics, 1986–2008; Tianjin Municipal Bureau of Statistics, 1986–2008; Zhejiang Provincial Bureau of Statistics, 1986–2008). As a result, the concentrations of sulphur dioxide (SO_2) and inhalable particulate matter (PM_{10}) in the study area heavily surpassed the standard issued by World Health Organization (WHO, 2005) (Fig. 1b, Fig.1c). In addition, the reach length with water quality exceeding national Grade III accounted for more than 25.4% except Fujian, Guangxi, Hainan, and Heilongjiang, and those of Tianjin, Shandong, Jiangsu and Shanghai were more than 55.6% (Beijing Municipal Environmental Protection Bureau, 2007; Fujian Provincial Environmental Protection Bureau, 2007; Guangdong Provincial Environmental Protection Bureau, 2007; Guangxi Provincial Environmental Protection Bureau, 2007; Hainan Provincial Environmental Protection Bureau, 2007; Hebei Provincial Environmental Protection Bureau, 2007; Heilongjiang Provincial Environmental Protection Bureau, 2007; Jilin

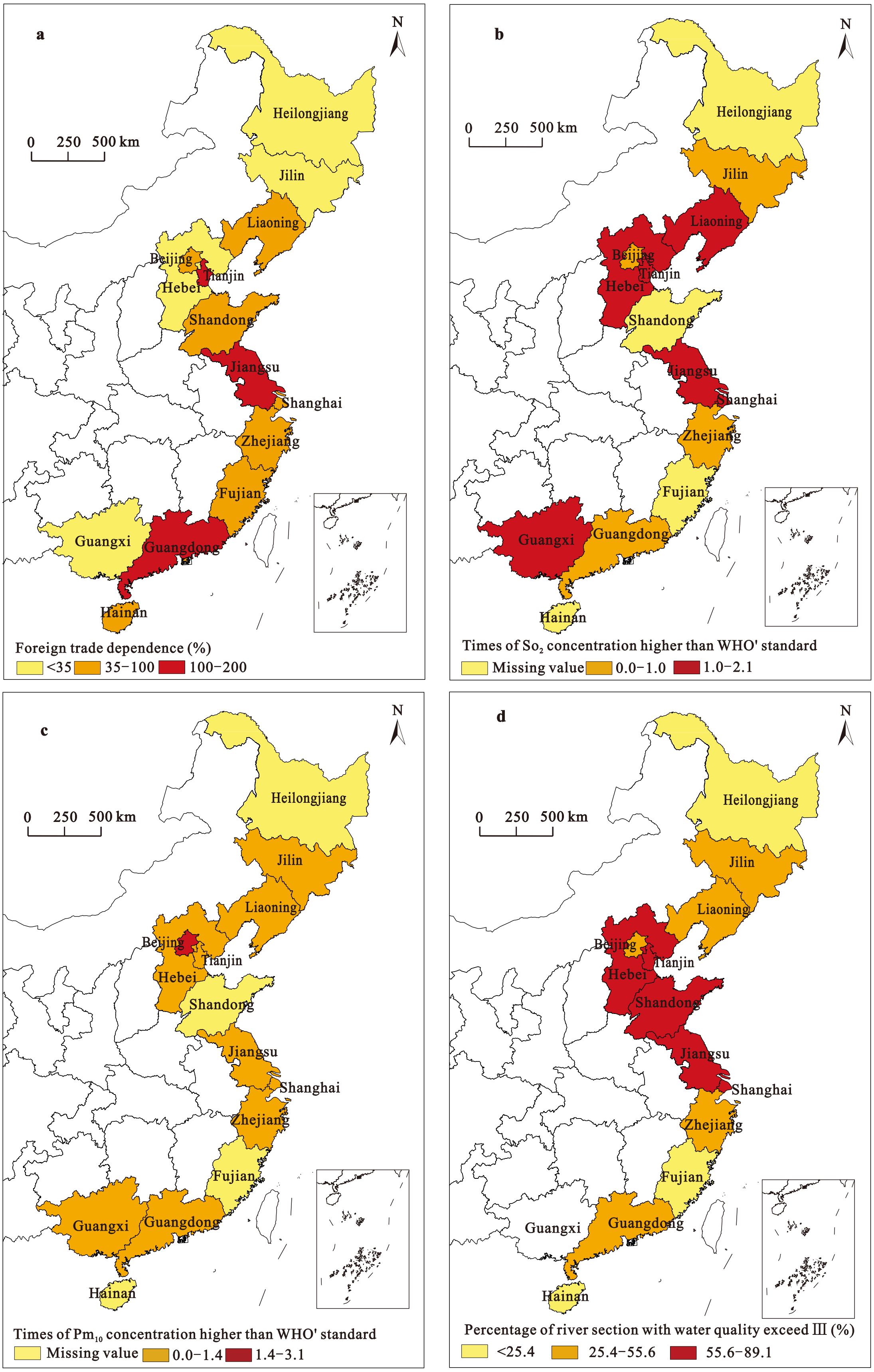

Fig. 1 Foreign trade dependence and environmental conditions of study area in 2007

Provincial Environmental Protection Bureau, 2007; Jiangsu Provincial Environmental Protection Bureau, 2007; Liaoning Provincial Environmental Protection Bureau, 2007; Shandong Provincial Environmental Protection Bureau, 2007; Shanghai Municipal Environmental Protection Bureau, 2007; Tianjin Municipal Environmental Protection Bureau, 2007; Zhejiang Provincial Environmental Protection Bureau, 2007).

2.2 Methods

2.2.1 Regression model

Based on the model established by Antweiler *et al.* (2001), the following model was used to carry out an empirical analysis on environmental effect of foreign trade in the study areas.

$$\ln Y_{it} = \lambda_i + \beta_{i1}\ln S_{it} + \beta_{i2}\ln I_{it} + \beta_{i3}\ln KL_{it} + \beta_{i4}\ln S_{it}\times\ln O_{it} + \beta_{i5}\ln I_{it}\times\ln O_{it} + \omega_i \quad (1)$$

where Y_{it}, S_{it}, I_{it}, KL_{it} and O_{it} denote total value of waste water discharge (10^4 t), regional average GDP (10^4 yuan/km^2), per capita GDP (yuan/person), per capita capital (yuan/person) and foreign trade dependence of the ith region in the tth year respectively, being applied to measuring environmental condition, economic scale, technical condition, structural state and development degree of foreign trade in sequence; λ_i and β_{ij} (j = 1, 2, 3, 4, 5) are coefficients; ω_i is the error term.

2.2.2 Cointegration analysis for panel data

Cointegration analysis for panel data mainly includes panel unit root test and panel cointegration test. When variables in Equation (1) are non-stationary, spurious regression will happen and make the result of regression has little practical significance. Therefore, this paper firstly inspect unit root test on these variables. If they are uniformity integrated variables (denoting as I (N), N represents the difference order, I (1) means first-order integration variable), cointegration test would be performed to get a steady equilibrium relationship exists among these variables in the long run.

2.2.2.1 Panel unit root test

For panel data, unit root test is conducted by the regression based on Equation (2), where cross-sectional series of each variable in Equation (1) is taken as a whole (Levin *et al*., 2002; Wu *et al*., 2008).

$$G_{it} = r_{it}G_{i(t-1)} + \mu_{it} \quad (2)$$

where G_{it} represents one variable of Y_{it}, S_{it}, I_{it}, KL_{it} and O_{it} in the unit root test; r_{it} is autoregressive coefficient; μ_{it} is mutually-independent heterogeneous disturbance term. When $|r_{it}| < 1$, G_{it} is a weakly-stationary variable, and when $|r_{it}|=1$, G_{it} is a non-stationary first-order integration variable (I (1)). On the base of r_{it}, various statistics of unit root test for panel data, such as LLC test, IPS test, Fisher-ADF test and Fisher-pp test, can be carried out simultaneously to judge whether the variable G_{it} is stationary or not (Im *et al*., 2003; Pedroni, 2004).

2.2.2.2 Panel cointegration test

According to the method for panel data discussed by Pedroni (2001), the following cointegration equation was constructed:

$$\ln Y_{it} = \alpha_{it} + d_{it}T + \eta_{i1}\ln S_{it} + \eta_{i2}\ln I_{it} + \eta_{i3}\ln KL_{it} + \eta_{i4}\ln S_{it}\times\ln O_{it} + \eta_{i5}\ln I_{it}\times\ln O_{it} + e_{it} \quad (3)$$

where T is time variable; α_{it} shows different fixed effects in cointegration relationship for each panel unit; d_{it} is coefficient; η_{i1}, η_{i2}, η_{i3}, η_{i4} and η_{i5} are the cointegration coefficient of each panel unit; e_{it} is mutually-independent heterogeneous disturbance term. On the base of residuals (e_{it}), Pedroni (2001) proposed seven cointegration statistics including Panel-v, Panel-ρ, Panel-pp, Panel ADF, Group-ρ, Group-pp and Group ADF, among which the former four and the later three are used to test on intraclass and interclass scale respectively. Generally, all statistics have good test abilities in large sample (T >100). However, Group ADF statistics have the strongest abilities for small sample (T < 20). Due to the time span as only 23 in this paper, Group ADF statistics were mainly considered in cointegration test.

2.2.3 Environmental effects induced by foreign trade development calculation

If the result of cointegration test inspected by Equation (3) indicated there is a steady equilibrium relationship among Y_{it}, S_{it}, I_{it}, KL_{it} and O_{it} in the long run, β_{i1}, β_{i2}, β_{i3} in Equation (1) are referred to as the percentage of dependent variable variation caused by 1% variation of corresponding independent variable, i.e., the environmental effect isolated by individual variation of corresponding regional economic scale, technical condition and structural state (isolating effects). Then, environmental effects induced by foreign trade development can be calculated with the methods proposed by Xu and Jin (2009):

$$R_j = K_j \times \beta_{ij} \quad (4)$$

where R_j is environmental effects induced by foreign trade development, j = 1, 2, 3; R_1, R_2, R_3 represent the environmental scale effect, structural effect and technical effect induced by variation of corresponding regional economic scale, technical condition and structural state; β_{ij} is isolating effects; K_j is influence coefficients:

$$K_1 = K_3 = \frac{d(EXP - IMP)}{(EXP - IMP)} \bigg/ \frac{d(GDP)}{GDP} \quad (5)$$

$$K_2 = \frac{d(KL)}{KL} \bigg/ \frac{d(GDP)}{GDP} \quad (6)$$

where *EXP*, *IMP*, *GDP*, *KL* and d represent total value of export, total value of import, gross domestic product, amount of capital stock and taking first order difference respectively.

2.3 Data source

In comparative analysis, the whole study area was divided into three groups by foreign trade dependence, i.e., high foreign trade dependence group (HFTD, with foreign trade dependence > 100%), including Tianjin, Shanghai, Jiangsu and Guangdong; medium foreign trade dependence group (MFTD, with foreign trade dependence between 35% and 100%), including Beijing, Liaoning, Zhejiang, Fujian, Shandong and Hainan; and low foreign trade dependence group (LFTD, with foreign trade dependence < 35%), including Hebei, Jilin, Heilongjiang and Guangxi (Fig. 1a). The data used in this paper were obtained from Provincial or Municipal Bureau of Statistics, Environmental Protection Bureau of the above 14 provinces and cities in the study area, with the time span from 1985 to 2007. The data of regional average GDP, per capita GDP, per capita capital, *etc*. were divided by price index. Some missing data were replaced by the estimated values through First Order Single Sequence Grey Model. As space is limited, these data have not be tabulated in this paper.

3 Empirical Results

3.1 Unit root test results

For robustness, four unit root test statistics, i.e., LLC, IPS, F-ADF and F-PP, were inspected on corresponding variables, and the results were listed in Table 1 and Table 2. Most statistics showed that the null hypothesis on unit root existing in $\ln Y_{it}$, $\ln S_{it}$, $\ln I_{it}$, $\ln KL_{it}$ and $\ln O_{it}$ could not be rejected. However, test results on first differences of variable logarithm sequence proved that the null hypothesis on unit root existing could be rejected at 1% significance level basically, i.e., all variable logarithm forms were non-stationary first-order integration variables in the model, upon which the cointegration analysis could be carried out.

3.2 Cointegration test results

On account of a certain autocorrelation among independent variables in cointegration model, Seemingly Unrelated Regression (SUR) was selected to estimate

Table 1 Test results of panel unit root test in study area and high foreign trade dependence group (HFTD)

Variable	Study area					HFTD				
	LLC	IPS	F-ADF	F-PP	Result	LLC	IPS	F-ADF	F-PP	Result
$\ln Y_{it}$	3.3	2.1	10.0	15.3	N	1.3	0.3	9.3	4.7	N
$d(\ln Y_{it})$	-13.1^{**}	-12.1^{**}	179.0^{**}	197.3^{**}	S	-7.4^{**}	-6.5^{**}	49.0^{**}	50.6^{**}	S
$\ln S_{it}$	7.4	11.5	1.4	0.34	N	3.4	5.3	0.1	0.0	N
$d(\ln S_{it})$	-6.7^{**}	-6.0^{**}	88.5^{**}	116.6^{**}	S	-5.0^{**}	-3.5^{**}	27.5^{**}	37.7^{**}	S
$\ln I_{it}$	8.1	10.9	6.5	3.2	N	3.7	5.3	0.1	0.0	N
$d(\ln I_{it})$	-5.4^{**}	-4.7^{**}	76.1^{**}	116.5^{**}	S	-3.4^{**}	-3.0^{**}	23.5^{**}	31.6^{**}	S
$\ln KL_{it}$	4.1	6.8	10.2	4.3	N	0.7	2.5	5.3	0.8	N
$d(\ln KL_{it})$	-8.8^{**}	-8.4^{**}	122.4^{**}	111.5^{**}	S	-5.1^{**}	-4.9^{**}	37.3^{**}	20.3^{**}	S
$\ln O_{it}$	–1.6	–0.0	33.8	37.4	N	–0.5	0.8	7.4	7.6	N
$d(\ln O_{it})$	-17.6^{**}	-16.4^{**}	240.0^{**}	309.0^{**}	S	-9.5^{**}	-8.1^{**}	62.1^{**}	62.6^{**}	S

Notes: F-ADF, Fisher-ADF; F-PP, Fisher-PP; ** and * denote 0.01 and 0.05 significance levels respectively; N, non-steady; S, steady; Y_{it}, S_{it}, I_{it}, KL_{it} and O_{it} are total value of waste water discharge (10^4 t), regional average GDP (10^4 yuan/km^2), per capita GDP (yuan/person), per capita capital (yuan/person) and foreign trade dependence of *i*th province (city) in *t*th year respectively; d means take first difference

Table 2 Test results of panel unit root test in medium foreign trade dependence group (MFTD) and low foreign trade dependence group (LFTD)

Variable	MFTD					LFTD				
	LLC	IPS	F-ADF	F-PP	Result	LLC	IPS	F-ADF	F-PP	Result
$\ln Y_{it}$	1.9	2.8	4.6	4.0	N	-2.4^{*}	0.3	9.9	6.7	N
$d(\ln Y_{it})$	-5.0^{**}	-5.1^{**}	50.2^{**}	64.8^{**}	S	-10.4^{**}	-10.2^{**}	79.9^{**}	82.0^{**}	S
$\ln S_{it}$	4.1	6.3	1.2	0.3	N	5.4	8.6	0.1	0.0	N
$d\ln(S_{it})$	-4.7^{**}	-4.0^{**}	39.0^{**}	45.5^{**}	S	-2.6^{**}	-2.7^{**}	22.0^{**}	37.5^{**}	S
$\ln I_{it}$	4.0	4.6	6.4	3.2	N	6.6	9.9	0.0	0.0	N
$d(\ln I_{it})$	-4.7^{**}	-3.9^{**}	37.9^{**}	50.0^{**}	S	-2.2^{**}	-2.1^{**}	20.3^{**}	35.0^{**}	S
$\ln KL_{it}$	2.1	4.1	2.4	1.0	N	5.2	4.9	2.5	2.5	N
$d(\ln KL_{it})$	-4.0^{**}	-4.9^{**}	47.0^{**}	31.3^{**}	S	-6.7^{**}	-4.9^{**}	38.1^{**}	60.1^{**}	S
$\ln O_{it}$	-3.0^{**}	–1.1	20.4	19.5	N	0.5	–0.2	6.9	10.3	N
$d(\ln O_{it})$	-13.1^{**}	-13.1^{**}	129.0^{**}	197.5^{**}	S	-7.1^{**}	-6.5^{**}	49.0^{**}	48.9^{**}	S

Notes: F-ADF, Fisher-ADF; F-PP, Fisher-PP; ** and * denote 0.01 and 0.05 significance levels respectively; N, non-steady; S, steady; Y_{it}, S_{it}, I_{it}, KL_{it} and O_{it} are total value of waste water discharge (10^4 t), regional average GDP (10^4 yuan/km^2), per capita GDP (yuan/person), per capita capital (yuan/person) and foreign trade dependence of *i*th province (city) in *t*th year respectively; d means take first difference

the equation in cointegration analysis for eliminating the effects on regression results. According to the results of cointegration analysis listed in Table 3, the null hypothesis on non-existent cointegration relationship could be rejected at 1% and10 % significant level for Group ADF statistics in study area, HFTD, MFTD and LFTD respectively. It was proven that a long-term equilibrium relationship existed among Y_{it}, S_{it}, I_{it}, KL_{it} and O_{it}. Table 4 shows the corresponding cointegration expression. As viewed from T-test value of estimation coefficient, favorable estimation results could be achieved by cointegration expression. As viewed from the signs of correlation coefficient, all isolating scale effects were positive, whereas all isolating technical effects were negative, and isolating structural effect was either positive or negative. Residual tests results showed that the autocorrelation among independent variables could be resolved by using SUR for estimating equation well.

3.3 Results of induced environmental effects

Using the methods proposed by Xu and Jin (2009), environmental effects induced by foreign trade development in the study area, HFTD, MFTD and LFTD are calculated and shown in Fig. 2, where the results are the average values of five-year time span, and the singular values in LFTD have been rejected.

Table 3 Panel data cointegration test results in study area, high foreign trade dependence group (HFTD), medium foreign trade dependence group (MFTD) and low foreign trade dependence group (LFTD)

	Study area	HFTD	MFTD	LFTD
Group ADF	–3.20 (0.001)	–1.59 (0.06)	–2.81 (0.003)	–1.34 (0.089)
Panel ADF	–3.81 (0.000)	–1.50 (0.07)	–3.25 (0.001)	–2.50 (0.006)

Note: Probabilities are listed in brackets

Table 4 Cointegration relationship in study area, high foreign trade dependence group (HFTD), medium foreign trade dependence group (MFTD) and low foreign trade dependence group (LFTD)

Variable	Study area	HFTD	MFTD	LFTD
$\ln S_{it}$	$1.060^{***}(5.8)$	$2.344^{***}(4.2)$	0.932(1.6)	$4.30^{**}(2.3)$
$\ln I_{it}$	$-0.137^{**}(-2.2)$	$-1.398^{*}(-2.0)$	$-0.392^{***}(-3.0)$	–2.452(–1.3)
$\ln KL_{it}$	$0.150^{**}(2.2)$	$0.169^{*}(1.8)$	$0.422^{***}(6.0)$	–0.075(–1.1)
$\ln O_{it}{}^{*}\ln S_{it}$	$-0.085^{***}(-3.3)$	$-0.473^{***}(-11.4)$	$-0.272^{***}(-2.9)$	–0.121(–0.6)
$\ln O_{it}{}^{*}\ln I_{it}$	$0.034^{*}(1.9)$	$0.263^{***}(8.1)$	$0.131^{***}(3.0)$	0.0174(0.2)
C	$6.994^{***}(10.2)$	$10.538^{***}(4.8)$	$7.427^{***}(6.1)$	$16.877^{**}(2.0)$

Notes: t-statistics are listed in brackets; ***, ** and * denote 0.01, 0.05 and 0.1 significance levels respectively; S_{it}, I_{it}, KL_{it} and O_{it} are regional average GDP (10^4 yuan/km^2), per capita GDP (yuan/person), per capita capital (yuan/person) and foreign trade dependence of *i*th province (city) in *t*th year respectively; C is constant term

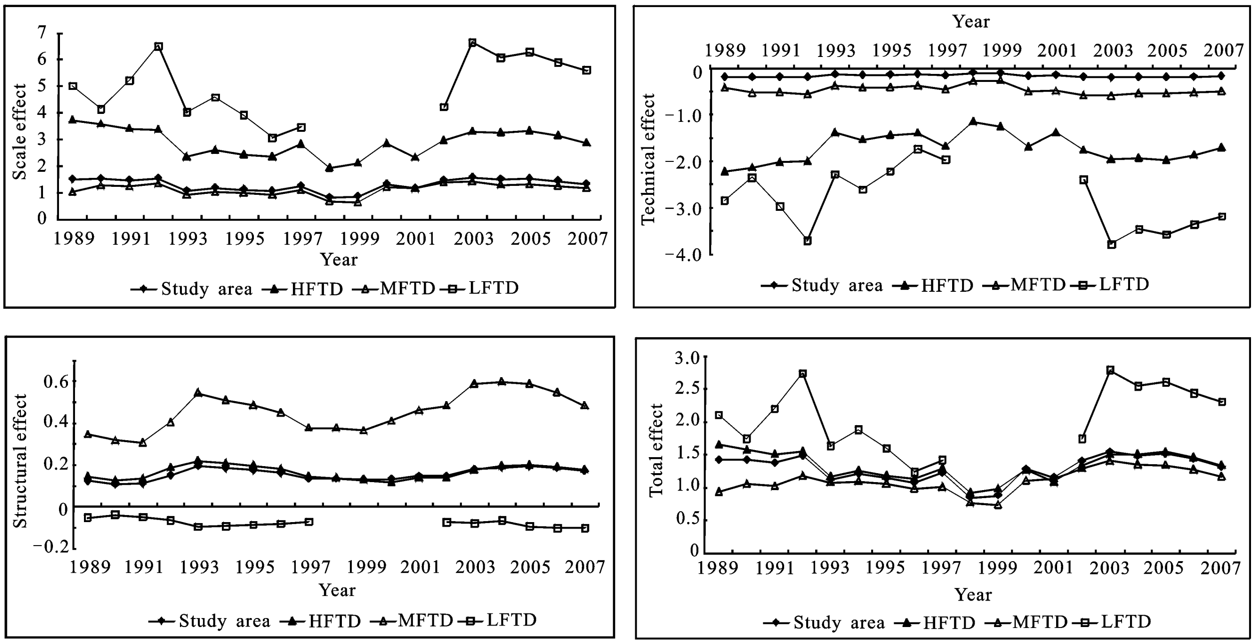

Fig. 2 Environmental effects of foreign trade in study area, high foreign trade dependence group(HFTD), medium foreign trade dependence group(MFTD) and low foreign trade dependence group(LFTD) (1989–2007)

4 Spatial Variation Analyses of Environmental Effects

4.1 Spatial variation of scale effects and cause analysis

As viewed from Fig. 2, scale effects are all positive in different groups. It is indicated that economic scale expansion induced by foreign trade development has a significantly adverse impact on the study area. According to the comprehensive average effect intensity in Fig. 3, the adverse impact reaches a maximum in LFTD (3.92), a medium in HFTD (2.88) and a minimum in MFTD (1.08). That is to say, significant spatial variations exist in scale effects of mid-eastern provinces and cities of China.

Generally, the intensity of scale effect has a positive correlation to regional foreign trade dependence. However, environmental scale effect induced by foreign trade development will be magnified when regional environmental policies are failure, environmental resources are used for free or public environmental protection products are deficient, leading to the positive

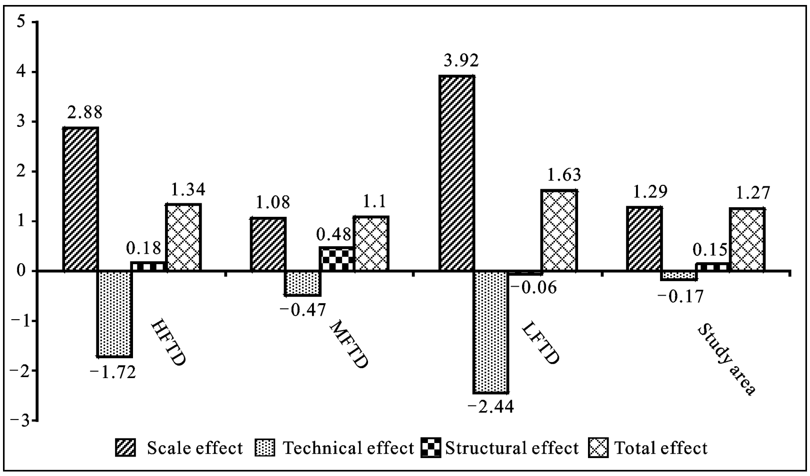

Fig. 3 Environmental effects of foreign trade in study area, high foreign trade dependence group (HFTD), medium foreign trade dependence group (MFTD) and low foreign trade dependence group (LFTD) (means value)

relationship with foreign trade dependence varied. Compared with HFTD and MFTD, LFTD are latecomers to export-oriented economic strategy with lower economic level. To achieve fast economic development, LFTD tends to decrease environmental protection requirements for industries. Additionally, due to lack of investments, public environmental products are relatively insufficient. As a result, more resources will be consumed and more pollution will be incurred for producing one unit of the same export product in these provinces and cities. It can be found in Table 5 that Hebei, Jilin and Guangxi in LFTD have significantly lower proportions of environmental protection investment in GDP than the provinces and cities in HFTD and MFTD. To a great extent, this is the major cause why environmental scale effect induced by foreign trade development in LFTD is even lower than HFTD.

4.2 Spatial variation of technical effects and cause analysis

Technical effects are all negative in different groups. Technical progress induced by foreign trade development in mid-eastern provinces and cities of China is beneficial to regional environmental improvement. Similarly, significant difference exists among different groups. Judging from Fig. 3, the absolute value of comprehensive average effect intensity of technical effect is shown with the sequence as LFTD (2.44) > HFTD (1.72) > MFTD (0.47).

Technology spillover from FDI and clean technology innovation under the demand of export destination countries are the main ways for regional technical progress promoted by foreign trade development, and the important reasons for impacting technical effect intensity as well. As shown in Table 6, average proportion of

Table 5 Proportion of environmental protection investment in GDP in some provinces and cities (%)

Province (city)	2007	2006	2005	2004	2003	2002	2001
Tianjin	2.88	–	2.59	3.09	3.42	2.65	2.75
Shanghai	3.00	3.10	3.03	3.07	3.00	3.05	3.08
Guangdong	2.70	2.50	2.50	2.71	2.67	2.47	2.30
Beijing	2.76	3.24	2.63	3.30	4.00	4.30	4.30
Zhejiang	–	1.80	1.63	1.87	2.52	2.72	2.39
Hebei	–	–	1.89	1.67	1.56	1.28	–
Jilin	–	1.96	1.62	1.84	1.93	1.98	–
Guangxi	–	–	1.21	–	–	–	–

Note: "–" is missing value

Source: Provincial or Municipal Bureau of Statistics of Tianjin, Shanghai, Guangdong, Zhejiang, Hebei, Jilin and Guangxi (2002–2008)

Table 6 Export destination and FDI use in different provinces and cities (2007)

Group	Province (city)	Proportion of export value to Europe, American and Japan (%)	Proportion of FDI from Europe, American and Japan (%)	Proportion of individual ownership in FDI (%)
HFTD	Tianjin	51.03	18.60	60.97
	Shanghai	61.96	25.14	76.30
	Jiangsu	59.73	15.57	83.13
MFTD	Guangdong	41.60	6.22	82.05
	Beijing	28.97	13.28	80.69
	Liaoning	50.89	13.37	–
	Zhejiang	57.60	9.25	67.18
	Fujian	59.47	4.36	81.77
	Shandong	53.96	15.26	78.97
LFTD	Hebei	47.74	10.13	–
	Jilin	57.51	–	–
	Heilongjiang	76.87	3.87	19.31
	Guangxi	34.68	1.86	39.04

Note: "–" is missing value

Source: Provincial or municipal Bureau of Statistics of Tianjin, Shanghai, Jiangsu, Guangdong, Beijing, Liaoning, Zhejiang, Fujian, Shandong, Hebei, Jilin Heilongjiang and Guangxi (2008)

FDI from Europe, American and Japan with higher technical level generally account for strikingly lower proportions in LFTD than other groups in 2007, which is unbeneficial to local technical progress to a certain degree. Due to weaker technical basis, LFTD is difficult to absorb excessively high technology, while FDI with small gap in local technology might be beneficial to promote technology among local enterprises. Additionally, the proportion of individual ownership in FDI is significantly lower, which provides a good opportunity for the generation of technology spillover effect. However, excessively high proportion of ownership in FDI restricts the spread of new and clean technology in MFTD. As to export value to Europe, American and Japan with higher clean technology innovation demand, LFTD account for a larger average proportion than HFTD and MFTD in 2007, which push clean technology innovation more popular in enterprises. These above two reasons magnify the technical effect in LFTD and make its technical effect greater than HFTD and MFTD. Such effect is particularly significant in Heilongjiang and Hebei.

4.3 Spatial variation of structural effects and cause analysis

Structural effect is either positive or negative in different groups, of which the comprehensive average effect in LFTD is –0.06, while that is 0.18 and 0.48 in HFTD and MFTD respectively (Fig.3). Orientation differences exist in the impact of industrial structure variations induced by foreign trade development on LFTD, HFTD and MFTD, but with insignificant effect intensity for all.

Provinces and cities in the study area are considered as the main regions with export-oriented economic development in China, where the export structure of different provinces and cities produces an important effect on local industrial structure. Therefore, the spatial variations of structural effects induced by foreign trade development can be well explained by variations in pollution intensity of export product structure in different groups. Taking Guangxi in LFTD for an example, the export proportion of ten manufactured products with top pollution intensity was reduced from 17.9% in 2003 to 13.4% in 2007 gradually (Guangxi Provincial Bureau of Statistics, 1986–2008). Specialized division of labor induced by foreign trade development resulted in the decreasing trend for pollution intensity of export product structure. The impact of foreign trade development on local industrial structure is beneficial to environmental improvement. Generally, HFTD and MFTD have lower pollution intensities of export product structure than LFTD. However, the export proportion of ten manufactured products with top pollution intensity tends to ascend in some provinces and cities. For example, that of Jiangsu and Shandong rose from 3.3% and 13.4% in 2003 to 6.5% and 16.3% in 2007 respectively (Shandong Provincial Bureau of Statistics, 1986–2008; Jiangsu Provincial Bureau of Statistics, 1986–2008). As a result, the adjustment of industrial structure induced by foreign trade development is unbeneficial to environmental improvement to a certain extent.

5 Conclusions

As to the study area or different groups, environmental scale effects induced by foreign trade development are all positive, whereas technical effects are negative, which is consistent with other empirical results basically. Except LFTD, structural effects in other groups and individual province or city are positive, which may be different from other research results achieved by domestic scholars. However, the intensity of structural effect is insignificant. Generally, technical effect of foreign trade with negative significance in the study area is unable to counterweigh the scale effect with positive significance. The rapid development of foreign trade is an important factor in causing serious eco-environmental problems to the mid-eastern provinces and cities of China.

As viewed from effect intensity, significant differences exist in environmental effects of foreign trade among different groups. HFTD and its individual province or city have higher positive scale effects and negative technical effects, but with medium positive structural effects. MFTD and its individual province or city have lower positive scale effects and negative technical effects, but with higher positive structural effects. LFTD and its individual province or city have higher positive scale effects and negative technical effects, but with lower negative structural effects. Besides development degree of foreign trade, the causes for spatial variations of environmental effect induced by foreign trade in the mid-eastern provinces and cities of China mainly include the differences in environmental policies, public environmental products provided by governments, export destinations, acceptance method of foreign industrial transfer and the impact on pollution intensity of export product structure.

Following the principle of 'coordinating generality and considering difference comprehensively', it is essential to issue a series of policies and countermeasures corresponding to the specialty of regional environmental effect induced by foreign trade. 1) In LFTD, emphases shall be made on formulating and implementing environmental protection policies, increasing the investment of public environmental products to meet the requirements of rapid foreign trade development, and gradually raising technical and clean production requirements for FDI. 2) In HFTD, on the base of maintaining high environmental protection requirements and investments, FDI shall be guided to establish enterprises with the organization more benefit to the spillover of advanced technology and clean production technology, and increase the proportions of joint ventures and cooperative business. Besides, the export proportions of clean high-tech products shall be raised through transferring to top chains of international trade division. 3) In MFTD, besides the same countermeasures to HFTD, export guidance policy shall be issued to change the increasing trend of high pollution-intensity product proportion in time, so as to avoid export product structure restricted at the bottom of international industrial chain.

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