

The Relationship between China's Industrial Space Agglomeration Process and Environmental Damage

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Abstract: On the basis of introducing the agglomeration function, the Copeland and Taylor models were used to establish a general linear model for the influence of industrial agglomeration on environmental quality; following, the difference in such influence at the different marketization levels is further distinguished and the linear model is expanded to the non-linear threshold model. On this basis, the panel data of 30 China's provinces and municipalities during the period of 2000-2009, as well as the threshold regression method proposed by Hansen (1999) were adopted to test the influence of industrial agglomeration on environmental pollution, where the marketization level is used as the threshold variable. Additionally, the sensitivity analysis is conducted for other industrial pollutants, and the results show the one that the model setting and test result in this paper are stable and reliable. Compared with the former literatures, the paper answers not only the question how industrial agglomeration affects environmental quality, but also introduces the threshold variable of level and further answers the question "what the conditions in which industrial agglomeration may are improve environment", which provides the rational reference for the formulation of related policy.

Keywords: Industrial space agglomeration; Environmental damage; Nonlinear model

1. Introduction

Over the past 40 years after China adopted the reform and opening-up policy, China's economy had come into the high-quality and new development era. Since the market-oriented reform of production factors pushes the rapid development of China's economy and the spatial agglomeration of industry, and such agglomeration achieves self-reinforcement through increasing scale return and positive feedback effect, it becomes the important engine of the rapid growth of China's economy. However, as same as those developing countries and those countries experiencing the economic transition, the large-scale development of industry increases the energy consumption and causes a series of serious environmental problems, such as atmospheric contamination, acid rain etc. Among which, the hazy weather under the focus of attention of people had shown the increasing trend in recent 50 years^[1-3]. Facing with the severe environment

situation, government sector of China has paid attention to it, and has promulgated multiple severe measures in succession to govern environmental issues. As China's market-oriented reform further continues and China's industrialization process constantly deepens, the problem whether the spatial agglomeration of industrial production may produce positive influence over environment and achieve the sustainable economic development is worthy of making the in-depth exploration; additionally, the issue how to take effective measures to control and reduce pollution and improve environment urgently needs to be solved^[4-6].

Focusing on the subject that industrial agglomeration affects environment quality, most of researches started the analysis from the perspectives of economic growth mode, technical level, foreign trade, economic activity had different influence on environment at the different economic development stages. On the basis of the aforesaid researches, domestic scholars of China discussed the problems related to industrial agglomeration and environmental issues of China. Researches in the literatures aforesaid provided much and beneficial references and inspirations; however most of overseas researches focused on the environmental issues in the economic development process based on the international data but did not consider the earliest stage of China's reform and development^[7]. Due to the influence of industrial development pushed by structure conversion on environment, domestic researches neglected an objective fact, namely the larger difference in the process of marketization and industrial agglomeration level of different regions of China, and neither cover the analysis on the differential influence of industrial agglomeration on environment quality from the perspective of different marketization level. Researches in this paper attempted to make a preliminary discussion on the problem^[8]. Firstly, it is generally recognized that the environmental pollution is resulted from the industrial agglomeration when discussing the problem of "how does the industrial agglomeration affect the environmental quality"^[9].

From the perspective of the paper, the consideration from the angle of industrial agglomeration and environmental quality is not enough, but more over the difference in the marketization level of different regions can be borrowed to judge the different influence of industrial agglomeration on environment. Secondly, most of previous research analyzed the relationship between

industrial agglomeration and environmental pollution under the framework of linear model; if introducing the difference in marketization level, the variable is possible to make the industrial agglomeration and environmental pollution show a non-linear relationship. Therefore, the paper mainly attempts to realize the following viewpoints: (1) theoretically introduce the agglomeration function into the Copeland and the Taylor model to establish a general linear model for the influence of industrial agglomeration on environmental quality; (2) add the variable of marketization level and expand the general linear model of (1) to the non-linear threshold model so as to distinguish the differential influence of industrial agglomeration on environmental quality at the different marketization level; (3) use the method of linear regression and the threshold regression to test the model of (1) and (2), compare the regression results, then make the sensibility test on different contaminants so as to verify the robustness of measurement results.

2. Theoretical Model

On the basis of introducing the agglomeration function, the Copeland and Taylor models were used to establish a general linear model for the influence of industrial agglomeration on environmental quality; following, the variable of marketization level was added to further expand the linear model to the non-linear threshold model so as to distinguish the difference of such influence at the different marketization level.

2.1 Basic Assumption

Assuming the production technology of representative enterprise is in the form of Cobb-Douglas, the scale return remains unchanged, and only input is two elements, namely capital and labor, so the production function can be expressed in the one as follows:

$$f(K, L) = K^a L^{1-a} \tag{1}$$

Where: K and L are respectively the capital and the labor income.

When plenty of similar enterprises get agglomeration within an area, the production function of representative enterprise can be written as:

$$F(K, L) = G(al) \cdot f(K, L) \tag{2}$$

Where: the agglomeration function $G(al) = \exp(\phi al)$ affects the yield level of enterprise through agglomeration effect or crowding effect; al is the industrial agglomeration level of the local area, the symbol of parameter ϕ depends on the size of agglomeration effect and crowding effect.

Assuming the representative enterprise produces a capital-intensive product X, and the contaminant Y is discharged simultaneously when producing the product X. The contaminant Y will bring the negative external effect to other producer or consumer, so it possesses the social cost. When the After the ownership is determined, enterprise must pay the social cost for the contaminant to be discharged (it can be in the form of pollution tax, sewage charge or purchase of pollution discharge permit)

and it is recorded as ρ . A rational enterprise can not discharge pollution without limitation but may spend a portion of production resources on reducing discharge capacity, so the percentage of the resource used by an enterprise for reducing pollution discharge to all production resources is expressed in $\theta \in [0, 1]$. When $\theta = 0$, enterprise will not use the resource for reducing pollution discharge but use all of them for product production; at this moment, the yield (F) therefrom represents the potential production capacity of enterprise. When $0 < \theta \leq 1$, enterprise may use the resource of θ for production, so the actual yield is $(1-\theta)F$; at this moment:

$$\text{The yield } X = (1-\theta) \cdot F(K, L) \tag{3}$$

The discharge capacity

$$Y = \varphi(\theta) \cdot F(K, L) \tag{4}$$

Where: the pollution discharge function $\Phi(\theta) = A^{-1}(1-\theta)^{1/b}$ is the decreasing function of θ , A is the technical level, and the parameter $b \in (0, 1), \varphi' \theta < 0, \varphi'' \theta > 0$.

Based on the Equation (3) and (4), the production function of X can be deduced as follows:

$$X = (AY)^b [F(K, L)]^{1-b} \tag{5}$$

Therefore X can be regarded as the output product of the input of two elements, namely contaminant Y and potential yield F, where the production function shows the feature as follows, namely the scale return remains unchanged; where b refers to the percentage of pollution element input to the total production cost

2.2. Production Decision

In accordance with the Equation (5), the decision of enterprise for producing X can be made by two independent processes, *i.e.*: exogenetic capital cost r and labor page ω , where the optimal capital-labor ratio can be selected to make the cost of enterprise for latent output F minimum; if the pollution discharge cost ρ and unit latent output cost c^F are given, the optimal discharge capacity Y and the latent output F can be selected to make the production cost c^X of enterprise for producing product minimum. Specifically it is expressed in:

$$c^F(\omega, r) = \min \{ r\tilde{K} + \omega\tilde{L}, F(\tilde{K}, \tilde{L}) = 1 \} \tag{6}$$

Where: \tilde{K}, \tilde{L} is respectively the latent output capital and labor input of enterprise.

If solving the optimization problem of the Equation (6) and (7), the first order condition to be obtained therefrom is respectively as follows:

$$(1-b)AY/bF = c^F/\rho \tag{7}$$

2.3. Pollution Discharge Selection

Assuming the price P^X of product X is given, the total income $TR = P^X X$, and the profit $\Pi = TR - TC, TC = c^F F + \rho AY$ is the total cost. If the market is a perfect competition market, so:

$$P^X X = c^F F + \rho AY \tag{8}$$

From the Equation (7) and (8),

$$Y = bP^X X / \rho A \tag{9}$$

If putting the Equation (1)-(3) into the Equation (9), the expression of pollution discharge capacity Y can be written as:

$$Y = M \rho^{-1} A^{-1} \exp(\phi al) (K^a L^{1-a}) \tag{10}$$

Where: $M = b\sigma(1-\theta)P^X$

Divide both sides of Equation (10) by L to obtain the expression of per capita pollution discharge capacity y :

$$y = M \rho^{-1} A^{-1} \exp(\phi al) k^a \tag{11}$$

Where: $y = Y/L, k = K/L$

Take the logarithm for both sides of the Equation (11), so:

$$\ln y = \ln M - \ln \rho - \ln A + \phi al + a \ln k \tag{12}$$

In developing country, the technology is only acquired by independent development and direct introduction from overseas; therefore the technical level A can be regarded as the function of development level rd and trade openness degree open ; specifically, it can be expressed as the one as follows:

$$\ln A = \lambda_0 + \lambda_1 \ln rd + \lambda_2 \ln open + \eta \tag{13}$$

Where: λ_0 is a constant item, λ_1 and λ_2 are respectively the influence coefficient of research level and trade opening degree for technical level, where $\lambda_1, \lambda_2 > 0$, the error term is $\eta \sim (0, \sigma^2)$.

According to the Equation (12) and (13), the per capita pollution discharge y can be written as:

$$\ln y = \xi_0 - \ln \rho - \zeta_1 \ln rd - \zeta_2 \ln open + \zeta_3 al + \zeta_4 \ln k + v \tag{14}$$

Where:

$\xi_0 = -\lambda_0 + \ln M, \xi_1 = \lambda_1, \xi_2 = \lambda_2, \xi_3 = \phi, \xi_4 = a, v = -\eta$ In accordance with the Equation (14), it can be known that the per capita pollution discharge is negatively related to the pollution discharge cost, R&D input and trade opening degree, and positively related to the per capita capital stock; whereas its correlation to the agglomeration level depends on the agglomeration effect and crowding effect. When the agglomeration effect is higher than the crowding effect, the per capita pollution discharge is negatively related to the industrial agglomeration effect; conversely, the per capita pollution discharge is positively related to the industrial agglomeration effect.

2.4 Influence of Marketization Level on Industrial Agglomerated Pollution Discharge

The marketization level ma affects the agglomeration effect and the crowding effect, and thereby makes the relationship between industrial agglomeration and environmental pollution change. When the marketization level is lower, the agglomeration effect is lower than the crowding effect and which results in the environmental pollution. On one hand, the regional economy with lower marketization level is relatively backward, where the local government may pay more attention to economic growth

and promote the industrial agglomeration to stimulate economy and drive the region to develop, and weaken the energy conservation and emission reduction; on the other hand, the agglomeration advocated by government may increase the rent-seeking dynamics of pollution discharge enterprise and reduce the dynamics of enterprise for energy conservation and emission reduction. When there is higher marketization level and the agglomeration effect is higher than the crowding effect, the pollution to environment may reduce. On one hand, the region with higher marketization level has more active economy and is easier to attract those enterprises having clean technology, whereby the technology diffusion and decrease of emission reduction cost are beneficial for enterprises within the area to realize emission reduction target; on the other hand, the relatively higher awareness of people for environmental protection is not only beneficial to reduce the supervision cost of government for pollution, but also beneficial to control pollution and promote local government to give more considerations for environmental protection when planning local industrial zones. Certainly the Equation (14) can be further expanded to the form as follows:

$$\ln y = \xi_0 - \ln \rho - \zeta_1 \ln rd - \zeta_2 \ln open + \bar{\zeta}_3 al + \zeta_4 \ln k + v \tag{15}$$

Where: $\bar{\zeta}_3 = \begin{cases} -|\phi|, (ma \in LL) \\ |\phi|, (ma \in HL) \end{cases}$, LL and HL represents the

area respectively with lower and higher marketization level.

3. Model Setup and Variable Description

3.1 Threshold Regression Method and Model Setup

In the regression analysis, the entire sample is usually divided into multiple samples for making respective regression analysis so as to test the stability of coefficient's estimate. Researcher needs to distinguish the different subsample by subjectively judging and determining the threshold valve of certain economic variable and further dividing the sample into multiple subsamples based on the threshold valve; however the results therefrom are not accurate since the threshold valve is not made the parameter regression or the significance test is not made (Javorcik, 2004). In view of the measurement method of the "threshold regression" developed by Levinsohn (2003), subsample can be endogenously divided in accordance with the native characteristics of data itself when establishing the threshold model of non-linear regression, which can thereby avoid the subjective deviation.

1. Single threshold model

$$y_{it} = \mu_i + \beta_1 X_{it} \cdot I(q_{it} \leq \gamma) + \beta_2 X_{it} \cdot I(q_{it} > \gamma) + \varepsilon_{it} \tag{16}$$

Where the sample data is $\{y_{it}, x_{it}, q_{it}\}_{i=1, \dots, N; t=1, \dots, T}$, i and t stands for the individual and the time, and y_{it} is the explained variable, x_{it} is the explanatory variable, q_{it} is the "threshold variable" of partitioning sample (it can be the "explaining variable" alternatively), γ is the threshold valve under estimate, μ_i reflects the

unobserved feature of individual, and $\varepsilon_{it} \sim a.i.d.N(0, \sigma^2)$ is the disturbing term. $I(\cdot)$ In order to indicate the function, namely if the expression in the brackets is true, the value will be "1"; if not, the value will be "0".

Estimate the threshold valve γ and the parameter β by using the nonlinear least square method (NLS), namely minimized residual sum of squares. If γ value is already determined, so $z_{it1} \equiv x_{it} \cdot I(q_{it} \leq \gamma), z_{it2} \equiv x_{it} \cdot I(q_{it} > \gamma)$, and the Equation (18) can be turned into the linear regression model, i.e.: $y_{it} = \mu_{it} + \beta_1 z_{it1} + \beta_2 z_{it2} + \varepsilon_{it}$. Use the OLS method to estimate $\beta_1(\gamma)$ and $\beta_2(\gamma)$ and calculate the residual sum of squares $SSR(\gamma)$; select γ to make $SSR(\gamma)$ minimize. The final obtainable parameter estimate is recorded as $(\beta_1(\hat{\gamma}), \beta_2(\hat{\gamma}), \hat{\gamma})$.

The threshold model inspection is composed of the significance test of threshold effect and the authenticity test of threshold estimate value. As for the problem whether there is the "threshold effect", the original hypothesis can be tested, i.e.: $H_0 : \beta_1 = \beta_2$. The residual sum of squares obtained from such constraint is recorded as SSR^* , and the residual sum of squares without constraint is recorded as $SSR(\hat{\gamma})$, and $SSR^* \geq SSR(\hat{\gamma})$. If the more the $[SSR^* - SSR(\hat{\gamma})]$ is, the higher the tendency to refuse the original hypothesis is. If the original hypothesis " $H_0 : \beta_1 = \beta_2$ " is true, there is no the threshold effect; if the original hypothesis is refused, there is the threshold effect and there is need to make a further test on the authenticity of threshold valve, namely when inspecting " $H_0 : \gamma = \gamma_0$ ", the likelihood ratio can be used to test $LR(\gamma)$ kinds of statistical magnitudes and then further calculate the confidence interval of γ , where the $LR(\gamma)$ is calculated as follows:

$$LR(\gamma) = [SSR(\gamma) - SSR(\hat{\gamma}) / \hat{\sigma}^2], \text{ where } \hat{\sigma}^2 \equiv \frac{SSR(\hat{\gamma})}{n(T-1)} \quad (17)$$

3.2. Multiple Threshold Model

Hypothesizing there are two threshold values, namely γ_1 and γ_2 for the threshold variable q_{it} , so the threshold regression model will be:

$$y_{it} = \mu_{it} + \beta_1 X_{it} \cdot I(q_{it} \leq \gamma_1) + \beta_2 X_{it} \cdot I(\gamma_1 < q_{it} \leq \gamma_2) + \beta_3 X_{it} \cdot I(q_{it} > \gamma_2) + \varepsilon_{it} \quad (18)$$

Where: the threshold valve $\gamma_1 < \gamma_2$. The parameter estimate and hypothesis test procedure in the dual threshold model are as same as those of the single threshold model. Before determining the second threshold valve, there is need to hypothesize the one that the first threshold valve γ_1 is known, explore the second

threshold valve γ_2 , and make the residual sum of squares $SSR(\gamma_2)$ minimize. Following the significance test of threshold effect can be conducted. If the original hypothesis " $H_0 : \beta_2 = \beta_3$ " is true, there is no "dual threshold effect". If the original hypothesis is refused, there is "dual threshold effect". After the second threshold valve is determined, we can fix it and then search the first threshold valve γ_1 to make its residual sum of squares $SSR(\gamma_1, \gamma_2)$ minimize. Lastly, the authenticity of dual threshold valve can be tested and the likelihood ratios test method can be used to test $LR(\gamma)$ statistical magnitude and then further calculate the confidence interval of γ_1, γ_2 .

3.3 Model Setup

In accordance with the Equation (17) and by referring to the thinking of Hansen (1999) threshold model, the measurement model is set as the following threshold regression form:

$$lnpol_{it} = \mu_{it} + \beta_1 al_{it} \cdot I(q_{it} \leq \gamma) + \beta_2 al_{it} \cdot I(q_{it} > \gamma) + \beta_{cv} cv_{it} + \varepsilon_{it} \quad (19)$$

Where: the subscripted i and t stands for the region and the year; pol_{it} stands for the pollution discharge, al_{it} stands for the industrial agglomeration level. cv_{it} stands for the control variable affecting the pollution discharge, including pollution discharge cost (expressed in $curb_{it}$), trade openness degree (expressed in $open_{it}$), research and development level (expressed in rd_{it}), and per capita capital stock (expressed in k_{it}). $q_{it}, \gamma, I(\cdot), \mu_{it}$ and ε_{it} have the meaning as same as those in the paragraphs aforesaid.

3.4. Variable Selection and Data Description

Explained variable: pollution discharge (pol). The pollution discharge includes atmosphere pollution, water pollution, solid waste pollution etc. However there is no unified aggregative indicator to measure environmental pollution degree. In view of the current situation of China, sulfur dioxide has higher percentage to the industrial pollution, and the statistical data of sulfur dioxide, relative to the other pollutants, is easier to acquire and has higher credibility. Therefore the per capita sulfur dioxide (SO_2) discharge (ration between regional industrial sulfur dioxide discharge and employed person) is used herein to measure the environmental pollution degree.

Core explanatory variable: industrial agglomeration level (al) Currently there are many indicators for measuring industrial agglomeration level, such as Gini coefficient, Hoover index, Ellison-Glaser index. By referring the method of Melitz (2008), Olley (1996), the location quotient is adopted to measure the industrial agglomeration level. The calculation formula for the location quotient (al_{ir}) of the industry r in the area i

can be expressed in the one as follows:

$$al_{ir} = \left(\frac{e_{it}}{\sum_i e_{ir}} \right) / \left(\frac{\sum_i e_{it}}{\sum_i \sum_i e_{ir}} \right) \quad (20)$$

Where: e_{ir} is the number of employed person engaged in the industry r in the area i . In this paper, the number of employed person engaged in industry in different provinces of China is used to calculate the location quotient of industry and measure the regional industrial agglomeration level.

Threshold variable: marketization level ($q \equiv ma$). In this paper, the marketization index of various provinces and districts during the period of 2001, namely the data provided by Chinese Marketization Index - Annual Report 2011 for Relative Progress of Regional Marketization in Various Provinces and Regions (Redding, 2004) was adopted as the measuring index. The marketization index measures comprehensively the marketized development conditions of various provinces and regions of China from five aspects, *i.e.*: relationship between government and market, development of non-state-owned economy, development degree of product market, development degree of element market, development degree of market intermediary organization and legal environment.

Control variable: (1) Pollution discharge cost ($curb$). The pollution discharge cost is the social cost that is paid by enterprise for the negative external effect caused by the pollution discharge; it is positively correlated to the pollution governance cost. Therefore in this paper, the percentage of regional investment for governing industrial pollution to GDP is adopted as the proxy variable of pollution discharge cost.

3.5. Trade Openness Degree(Open) .

In this paper, the percentage of total regional trade import and export amount to GDP is adopted to measure the trade openness degree of a certain region. The total trade import and export amount is adjusted into Renminbi in accordance with the middle rate of foreign exchange of different years.

3.6. Research and Development Level(RD) .

In this paper, the percentage of the expenditure of regional research institution for research and test development (R&D) to GDP is adopted to measure the R&D level of a certain region. The more the R&D input is, the larger the support of the region for scientific research innovation is, including the support to the research and development of environmental protection technology and which is beneficial for reducing the discharge of pollutant.

3.7. Per Capita Capital Stock(k).

In this paper, the annual average balance of fixed asset's net value of regional industry is adopted to represent the capital stock, and the average number of employed person engaged in industry is adopted to represent the quantity of labor force. The sample data comes from the statistical

yearbook of 30 provincial-level administrative regions during the period from 2001 to 2010 (since certain data of Tibet is missing, it is not incorporated into the sample range) and China's Industrial Statistical Yearbook during the period from 2001 to 2010, whereas the marketization index comes from "China's Marketization Index - Report 2011 for Relative Marketization Progress of Various Regions".

4. Measurement Results and Analysis

4.1 Basic Model Analysis

The model in this paper is set as the threshold model having the fixed effect, so the Hausman test is firstly made to judge whether the selection of fixed effect model is workable. In view of the inspection result, the P value of Hausman test is 0.0000 and the original hypothesis is refused at the significance level of 1%; therefore the threshold model having the fixed effect is adopted.

In accordance with the thinking of Hansen (1999), it is needed to test the threshold effect firstly. If using the marketization level (ma) as the threshold variable, the single threshold effect and the dual threshold effect at the significance level of 1% are significant, and the single threshold and dual threshold hypothesis pass the inspection. Afterwards, array the sample in the ascending order in accordance with the size of threshold variable ma , estimate the sample in turn, and then select the threshold valve γ corresponded to the minimized residual sum of squares.

Display of estimate result of dual threshold: $\gamma_1 = 3.050$, $\gamma_2 = 4.580$. Obviously, the one using the marketization level (ma) as the threshold variable can refuse the original hypothesis of linear relationship, the dual threshold effect should be significant; thereby, the non-linear relationship between industrial agglomeration and environmental pollution can be validated.

According to the threshold regression result of industrial agglomeration and environmental pollution, the influence of industrial agglomeration on environmental pollution is different at the different marketization levels (ma) and the significant threshold feature shows up, namely when the marketization level (ma) is lower than 3.050, the influence coefficient of industrial agglomeration on environmental pollution is 0.5386; when the marketization level (ma) is 3.050-4.580, the influence coefficient can reduce to 0.2514; when the marketization level (ma) is higher than 4.580, the influence coefficient further reduces to -0.4192. Obviously the relationship between industrial agglomeration and environmental pollution is different from the linear relationship in former literatures and it has a turning point, namely the threshold valve; it brings not the monotonic increment or decrement to the influence of industrial agglomeration on environmental pollution, but the reverse U feature. When the marketization level is lower, industrial agglomeration may result in

environmental pollution, and such negative influence may weaken as the marketization level improves; when the marketization level steps over higher threshold valve, industrial agglomeration may have active influence on environment and which may help to improve environment quality. The possible explanation is: when the marketization level is at the lower level, the crowding effect of industrial agglomeration is higher than the agglomeration effect, and the resource consumption rate exceeds the regeneration rate of resource and the bearing capacity of environment, which results in the environmental pollution increase; when the marketization level improves, the soft environment, such as law, institutional system etc. improves, environmental protection technology innovation increases, pollution governance efficiency improves, agglomerated industry's symbiosis improves, and agglomeration effect increases, thereby the damage of industrial agglomeration on environment reduces; moreover as the marketization level further improves, the agglomeration effect will intensify and become higher than the crowding effect, which may give full play to the role of improving environment quality and reducing pollution. The estimate coefficient of pollution control expense is positive and such result is rightly contrary to the expected result; since China's governmental subsidy for environmental protection and China's governmental loan for environmental protection aim at the pollutant governance of enterprises, both of them have incentive effect on enterprise for adopting cleaner production technology; the trade openness coefficient is positive, where the possible explanation is: the economic structure change induced by trade freedom brings the dual environmental effect; however the negative effect brought by "pollution heaven" exceeds technological advance effect and factor endowment effect. The possible explanation for the one that the research and development level does not pass the significance test is: as the microcosmic individual, enterprise pays more attention to the project that may bring benefit in a short time, so research and development investment may prefer to improve product technology instead of environmental protection technology; therefore the technological

advance has no significant function for the improvement of environmental quality. The coefficient of per capita capital stock is positive, which is consistent with the Leibkinsky's theorem. The improvement of per capita capital stock will result in the improvement of industrial yield of capital-intensive industry and thereby increase the discharge of pollutant.

Additionally according to the linear estimate result of industrial agglomeration for environmental pollution, the estimate coefficient of industrial agglomeration is positive, and it passes 1% significance test; such result validates again the one that industrial agglomeration may result in environmental pollution. However the industrial agglomeration coefficient is 0.5810 and which is higher than the threshold model's estimate result. Since the difference in the marketization level of various provinces and municipalities is not distinguished in the linear estimate, the non-linear relationship between industrial agglomeration and environmental pollution is neglected. Therefore the conclusion from the linear estimate method may miss important explanations.

4.2. Sensibility Analysis

The industrial pollution is composed of industrial wastewater pollution, industrial waste gas pollution and industrial solid waste pollution. In this paper, the industrial wastewater pollution and the industrial waste gas pollution are selected as the explained variables to make the sensitivity analysis. The estimate result of the Equation (20) by using the threshold regression method through three kinds of pollutants is shown by Table 1, where the dual threshold effect passes the significance test and its regression coefficient is not totally consistent with the inspection symbol when the sulfur dioxide is selected as the pollution parameter; however the coefficient tends to decrement. After the marketization level exceeds the high threshold value, industrial agglomeration may generate waste water and waste gas pollution, but such adverse influence is significantly reduced and most of control variables pass the significance test; therefore the quantitative analysis in this paper has better robustness.

Table 1. Sensitivity Analysis Results

| Explanatory variable | SO ₂ | gas | water |
|-----------------------------------|-------------------|-------------------|------------------|
| $al(ma \leq \gamma_1)$ | 0.5601*** (3.67) | 0.8297*** (6.04) | 1.1063*** (9.07) |
| $al(\gamma_1 < ma \leq \gamma_2)$ | 0.2597** (2.08) | 0.6614*** (4.09) | 0.9712*** (9.42) |
| $al(ma > \gamma_2)$ | -0.4312** (-2.81) | 0.4048*** (4.02) | 0.7876*** (7.56) |
| <i>Incurb</i> | 0.0753*** (2.51) | 0.0602 (1.29) | 0.0401** (2.15) |
| <i>Inopen</i> | 0.1967*** (3.54) | 0.1298** (2.04) | -0.1038 (-1.38) |
| <i>Inrd</i> | -0.0021 (-0.03) | -0.0582 (-0.80) | 0.0601 (-1.46) |
| <i>Ink</i> | 0.1017** (2.87) | 0.8802*** (18.04) | 0.0503 (1.15) |
| Constant term | 3.0769*** (13.01) | 0.1201 (0.34) | 1.5025*** (6.73) |
| 1 st threshold valve | 3.051 | 6.298 | 4.480 |

| | | | |
|---------------------------------|------------------------|------------------------|------------------------|
| | [3.050,3.050] | [6.501,6.802] | [4.084,4.536] |
| 2 nd threshold valve | 4.731 [4.160,4.587] | 8.186 [3.145,8.397] | 8.053 [7.698,8.403] |

Note: the value in the round brackets is the statistical magnitude t corresponded by all coefficients, **, **, * represents respectively the one passed the significance test at the level of 1%, 5% and 10%; the value in the middle brackets shows the confidence interval (95% of threshold values).

5. Conclusions

On the basis of introducing the agglomeration function, the Copeland and Taylor models were used to establish a general linear model for the influence of industrial agglomeration on environmental quality; following, the difference in such influence at the different marketization levels is further distinguished and the linear model is expanded to the non-linear threshold model. On this basis, the panel data of 30 China’s provinces and municipalities during the period of 2000-2009, as well as the threshold regression method proposed by Hansen (1999) were adopted to test the influence of industrial agglomeration on environmental pollution, where the marketization level is used as the threshold variable. Additionally, the sensitivity analysis is conducted for other industrial pollutants, and the results show the one that the model setting and test result in this paper are stable and reliable. Compared with the former literatures, the paper answers not only the question how industrial agglomeration affects environmental quality, but also introduces the threshold variable of level and further answers the question “what the conditions in which industrial agglomeration may are improve environment”, which provides the rational reference for the formulation of related policy. The conclusion of the paper includes:

Firstly, industrial agglomeration and environmental pollution have the significant “reverse U relationship” during the period of sample: when the marketization level is lower, industrial agglomeration may result in environmental pollution, and such negative influence may weaken as the marketization level improves; when the marketization level steps over higher threshold valve, industrial agglomeration will cause active influence on environment and help to reduce environmental pollution. Therefore, the differentiated polices should be formulated in accordance with the different features of regional marketization levels so as to solve environmental problem. In the area with lower marketization level, governmental sector should work hard to push the marketization reform of environmental protection field to turn the government-led industrial agglomeration pattern to the tax/price-regulated market selection pattern; in the area with higher marketization level, governmental sector should give full play to the agglomeration effect and improve the environmental quality. Therefore, the one to promote the agglomerated enterprise to develop clean technology through incentive mechanism, reduce the marginal cost of pollution governance, make industrial pollution discharge reach the scale economy, further improve the constraint of environmental laws and regulations, promote enterprise to improve environmental risk prevention and control and improve environmental management level will become

the vigorous supplement of government sector for environmental regulatory system.

Secondly, pollution control input does not give full play to the role of improving environmental quality. During the sample period, the pollution control input of every province was only 0.2% of GDP, where the insufficient capital input reduces the expected pollution control result. Meanwhile, pollution control input focuses on controlling the existing pollution, instead of constraining the pollution source; therefore the execution result of pollution control input is very limited. Certainly all of us should attempt the marketization operation of pollution control, attract multiple channels of capital to flow to the environmental protection field, increase the internal dynamics of enterprise for making environmental protection innovation and give full play to the environmental protection function of industrial agglomeration.

Thirdly, trade freedom deteriorates environmental quality. In accordance with the viewpoints of Krugman (1990), trade freedom will amplify the local market effect and make the industrial agglomeration increase. Therefore in order to avoid the negative effect caused by “pollution heaven”, the ones of introducing capital and making environmental protection should be taken as the dual goals, and the strict environmental control on foreign capital should be launched. Besides, it is better to lead foreign capital to transfer towards the clean industry or department, optimize trade structure, encourage domestic enterprises to undertake the advanced environmental protection technology of overseas enterprise, learn the advanced and efficient experience of overseas enterprises in environmental control and governance, and then push China’s new round of supply side reform and improve the quality and ecological benefits of production system supply.

Acknowledgements

This work was financially supported by the Key project of the National Social Science Foundation of the year 2018 (18AJY013); the 2017 National Social Science foundation project (17CJY072); the 2018 Fujian Social Science Planning Project (FJ2018B067); The Planning Fund Project of Humanities and Social Sciences Research of the Ministry of Education in 2019 (19YJA790102); the 2018 planning project of philosophy and social science of Zhejiang Province (18NDJC086YB).

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