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The Impact of Manufacturing Agglomeration on Environmental Pollution

A case study of the middle and lower reaches of the Yangtze River

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***Abstract*—Based on the technology spillover effect and the "pollution paradise" hypothesis, this paper introduces the manufacturing agglomeration variables and foreign direct investment variables on the basis of the STIRPAT model, and uses the location entropy index to measure the manufacturing agglomeration level, while selecting industrial sulfur dioxide emissions as the measurement of environment pollution. The empirical results show that there is an inverted "N"-type curve relationship between the level of manufacturing agglomeration and the environmental pollution in the middle and lower reaches of the Yangtze River.**

Keywords*—*STIRPAT model; manufacturing agglomeration; environmental pollution; location entropy

I. INTRODUCTION

As a basic industry for China's development, manufacturing industry can directly reflect China's productivity level and is an important support for economic development. However, after the negative impact of long-term extensive operation, the environment is seriously polluted at the expense of production factors (energy and resources, etc.), especially in the traditional manufacturing industry [1]. As one of the important organizational forms of regional industrial organizations, industrial agglomeration has become a common mode of economic development in the world.

With the continuous improvement of industrial agglomeration level, on the one hand, with its specialized division of labor and mutual cooperation, as well as the positive effect of scale brought by agglomeration, knowledge technology spillover effect and benign competition effect, it can effectively promote regional economic development [2]. On the other hand, the negative externalities generated by it are also increased due to the concentration of industrial activities, which will inevitably have a certain negative impact on the ecological environment and hinder the sustainable development of the economy [3].

At present, the development of China's manufacturing industry has shown a clear trend of industrial agglomeration. While the external economy brought by the increasing degree of agglomeration greatly promotes economic growth, the environmental pollution becomes more and more serious. In order to be able to formulate and implement relevant policies clearly and efficiently, it is important to study the impact of manufacturing agglomeration on environmental pollution. After clarifying the impact mechanism between the two, it is conducive to giving full play to the role of industrial agglomeration, optimizing resource allocation, and enhancing industrial competitiveness without prejudice to the environment or even effective improvement of the ecological environment, and actively promote regional, regional and even national green economy growth.

The middle and lower reaches of the Yangtze River cover seven provinces and cities including Anhui, Hubei, Hunan, Jiangxi, Jiangsu, Shanghai and Zhejiang. The region is rich in natural resources, developed water and land transportation system, opened to the outside world earlier, and the economy is developing rapidly. And it is also an important industrial base in China. The main industries are steel, machinery, electricity, textiles, chemistry and so on. Jiangsu, Shanghai and Zhejiang in the eastern part of the region are the most economically developed regions in the region, with comprehensive strength, sufficient resources such as talents and funds, and strong innovation capabilities. The Anhui, Hubei, Hunan, and Jiangxi in the central part of the region which have the geographical advantages of linking the east and west, large ecological environment capacity, complete industry, and relatively solid industrial foundation, is one of the more representative manufacturing clusters with higher development maturity in China.

The existing literature studies mostly focus on national data, but less on regional data. In order to clearly understand the current development of the middle and lower reaches of the Yangtze River, this paper selects the panel data of 7 provinces and cities in the region in 2008-2017, uses STIRPAT model and extends it, and carries out empirical research on the impact of manufacturing agglomeration on environmental pollution to clarify the relationship between the two.

II. MODEL BUILDING AND VARIABLES DESCRIPTION

A. Model Building

As environmental problems become more serious, more and more scholars are beginning to pay attention to the causes and discuss the impact of human factors on environmental pressure. Ehrlich and Holdren (1971) proposed an environmental stress model, namely the IPAT model (I=P×A×T), which can easily and feasibly describe the human influence factors of environmental problems, but it is not difficult to find that the model exists limitation according to its formula [4]. In order to make up for the defects of the IPAT model that simply deal with the relationship between environmental problems and their influencing factors into the same proportional linear relationship and limit other social factors that may affect the environment, Dietz et al. (1994) proposed a stochastic regression impact model, namely STIRPAT model, forms an expandable environmental impact assessment model by adding random variables [5]. The formula is as follows:

$$I = a\,P^b A^c T^d e \tag{1}$$

In this form, I is environmental pressure, P is population, A is affluence, T is technical, a is the constant term, b, c and d are the exponential terms of P, A and T, respectively, and e is the error term. It can be seen that the IPAT model is actually a special form of the STIRPAT model, when $a=b=c=d=e=1$. At the same time, according to the "pollution paradise" hypothesis, due to the enhancement of environmental regulation and environmental awareness in developed countries, those enterprises with higher environmental costs will transfer the high-contamination and high-energy consumption part of the industrial chain to developing countries, resulting in a large increase in pollutant emissions. Therefore, based on the STIRPAT model, variables reflecting manufacturing agglomeration and variables reflecting foreign direct investment will be introduced, and variables reflecting the population size (A) will be excluded [6]. After the corresponding expansion of the model, the new model formula is as follows:

$$I_{it} = a\,A_{it}^{\,c} F_{it}^{\,b} T_{it}^{\,d} M_{it}^{\,\eta} e_{it} \tag{2}$$

Where F is foreign direct investment, M is manufacturing agglomeration factor, b and η are the exponential terms of F and M respectively, i Is the province, t Is the year, and other variables denote the same meaning as in Eq.(1). In order to better analyze the impact of various factors on environmental pollution, logarithmically processing Eq.(2) to obtain

$$lnI_{it} = lna + clnA_{it} + blnF_{it} + dlnT_{it} + \eta lnM_{it} + e_{it} \tag{3}$$

In the meantime, considering the possible nonlinear relationship between environmental pollution and manufacturing agglomeration, the factor of manufacturing agglomeration in the model is decomposed into three items $\eta_1 lnM_{it}$, $\eta_{2}(lnM_{it})^2$ and $\eta_{3}(lnM_{it})^3$, to verify whether there is inflection point of environmental pollution with the increase of industrial agglomeration in manufacturing industry [7], the model is transformed into

$$lnI_{it} = lna + clnA_{it} + blnF_{it} + dlnT_{it} + \eta_{s}(lnM_{it})^s + e_{it} \tag{4}$$

Where s represents the value of the n-th order coefficient of the industrial agglomeration variable ($s=1,2,3$).

B. Variables and Data Description

The research sample of this paper is selected as the panel data of 2008-2017 in 7 provinces and cities in the middle and lower reaches of the Yangtze River in China. The relevant data are from the China Statistical Yearbook and the statistical yearbooks of various provinces and cities during 2009 to 2018. The relevant variables in the model of this paper are described as follows:

1) The environmental stress factor (I), is the dependent variable. Drawing on the methods used by Yuan Yijun and Xie Ronghui (2015), industrial sulfur dioxide emissions are used as a measure of environmental pollution [8].

2) The degree of affluence (A), is an independent variable. This article uses the per capita GDP of each region to measure. Areas with higher levels of economic development often have larger industrial scales, and energy consumption and pollution emissions are relatively more.

3) Foreign direct investment (F), is an independent variable. This paper selects foreign direct investment (FDI) actually used in each region as an indicator. With the trend of economic globalization and the increasing degree of China's opening up to the outside world, the introduction of FDI has also exerted a certain influence on environmental pollution while promoting economic development. One view is that the inflow of foreign capital brings a higher level of technology and can effectively reduce environmental pollution. The other is based on the "pollution paradise" hypothesis. It is believed that foreign direct investment as one of the channels for the transfer of highly polluting industries in developed countries will aggravate the environmental pollution problem in the invested areas.

4) The technical level (T), is an independent variable. In this paper, the energy consumption per unit of GDP is used as an indicator, that is, the regional energy consumption is divided by the regional GDP. The level of technology directly affects the efficiency of energy use, and the improvement of technology can effectively improve the regional environmental conditions.

5) The manufacturing agglomeration factor (M), is the core-independent variable. At present, there are many methods for calculating industrial agglomeration at home and abroad, such as industry concentration, HHI(Herfindahl-Hirschman index), spatial Gini coefficient, and EG index. In this paper, the location entropy is used to measure the comparative advantage of the inter-regional industry. The formula is as follows:

$$LQ_{ij} = (X_{ij} / \textstyle\sum_i X_{ij}) / (\sum_j X_{ij} / \sum_i \sum_j X_{ij}) \tag{5}$$

In the Eq.(5), LQ_{ij} is the location entropy of the industry i in the j region, X_{ij} is the employment number of the industry i in the j region, $\sum_i X_{ij}$ is the employment of all industries in the j region, $\sum_j X_{ij}$ is the employment number of the industry i in all regions of the country, and $\sum_i\sum_j X_{ij}$ the number of employed people in all industries in all regions of the country. The larger the value of LQ_{ij}, the higher the concentration level of the industry in the region. It is generally believed that $LQ_{ij} >1$ indicates that the industry has obvious comparative advantages and the industrial agglomeration level is higher, $LQ_{ij} =1$ indicates the regional concentration of the industry is not high, and $LQ_{ij} <1$ indicates that the concentration of the industry in the region is low, which is at a comparative disadvantage relative to the national level.

III. EMPIRICAL ANALYSIS AND RESULTS

This paper uses Eviews6.0 software to carry out regression analysis on the above model to study the impact of manufacturing agglomeration on environmental pollution in the middle and lower reaches of the Yangtze River. The sample time is from 2008 to 2017. The descriptive statistics of each variable are shown in Table I.

Firstly, the unit root test is carried out on the panel data of seven provinces and cities. According to the results of LLC test, ADF-Fisher test and PP-Fisher test, the variables *lnI*, *lnT*, *lnM*, $(lnM)^2$ and $(lnM)^3$ do not reject the original hypothesis, namely there is a unit root. Therefore, the first-order and second-order difference tests are carried out successively. It is found that the variables other than the variable I are stable after the first-order difference, and the variable I is also stable after the second-order difference. On the basis of the unit root test, the co-integration test was carried out, and it was found that the Panel-PP and Group-PP test results were all passed significantly. Therefore, it is considered that there is a co-integration relationship between the variables, and panel data analysis can be performed. Since the choice of the model will affect the validity of the parameter estimation, in order to determine whether the estimation is a fixed effect model or a random effect model, the Hausman test is performed in this paper. The test results show that the original hypothesis is accepted at a significant level of 1%. So this paper uses stochastic effect model to Estimation and analysis of panel data.

As shown in Table II, according to the regression results of the sample data of 7 provinces and cities in the middle and lower reaches of the Yangtze River during the period 2008-2017, it can be found:

1) the impact of affluence on environmental pollution is positive at the 1% significant level. In other words, at this stage, the improvement of regional economic development has not effectively improved the problem of environmental pollution. Considering that although the current regional economy has developed to a certain stage, people have abandoned the pursuit of a single economic development benefit and began to pay attention to the coordinated development of the economy and the ecological environment, also the intensity of environmental regulation and protection is also constantly strengthening, but in the actual operation and implementation, it still faces many difficulties and fails to implement the policy. The economic development still brings certain pressure on the environment.

2) Foreign direct investment has a significant positive effect on environmental pollution, that is, the introduction of foreign direct investment has further aggravated environmental pollution, which has verified the "pollution paradise" hypothesis to some extent. With the continuous inflow of foreign capital, some highly polluting industrial chains and production processes have also been transferred to China.

3) The impact of technical level on environmental pollution is positive at the level of 5% significance. This paper uses the energy consumption per unit of GDP as a measure. The increase in the value of this indicator represents an increase in the energy consumption per unit of GDP, and the technical level actually decreases. Therefore, the regression results show that the reduction of the variable reflecting the technical level which means that the technical level is continuously improving, can reduce the emission of corresponding pollutants, and thus significantly improve environmental pollution.

4) The primary and secondary coefficients of the manufacturing agglomeration are negative at the 1% significance level, and the cubic coefficient is negative at the 5% significance level, presenting an inverted "N"-type curve relationship. In other words, environmental pollution decreases with the increase of industrial agglomeration level in the initial stage, increases with the increase of industrial agglomeration level after reaching a certain stage, and finally decreases with the increase of agglomeration level after a turning point.

TABLE I. DESCRIPTIVE STATISTICS OF THE VARIABLES

Variables	Mean	Max.	Min.	SD	Skewness	Kurtosis
lnI	3.71	4.68	0.24	0.72	-1.98	9.19
lnA	10.45	11.58	9.19	0.60	-0.16	2.23
lnF	13.83	15.09	9.98	0.77	-1.76	10.28
lnT	-0.52	0.12	-1.01	0.27	0.58	2.69
lnM	-0.34	0.45	-1.56	0.57	-0.24	1.94
$(lnM)^2$	0.44	2.44	0.00	0.56	1.93	6.26
$(lnM)^3$	-0.41	0.09	-3.81	0.81	-2.59	9.43

TABLE II. REGRESSION RESULTS OF THE PANEL DATA

Variables	Coefficient	t-Statistic	Prob.
lnA	1.275***	15.90	0.000
lnF	0.123**	2.257	0.028
lnT	0.950**	2.570	0.013
lnM	-0.830***	-4.726	0.000
$(lnM)^2$	-1.518***	-3.782	0.000
$(lnM)^3$	-0.478**	-2.288	0.026
cons	-10.63***	-8.629	0.000
R-squared	0.899		
Adjusted R-squared	0.871		
F-statistic	31.93***		

[a] Note:***,** and * denotes significance higher than 1, 5 and 10%, respectively.

According to the above empirical results, it is found that there is an inverted "N"-type curve relationship between manufacturing agglomeration and environmental pollution. After calculation, the two inflection points of the curve are -1.7963 and -0.3225, respectively. That is to say, when the agglomeration level is lower than -1.7963, the environmental pollution decreases with the increase of the agglomeration level. This is because in the initial stage, a certain degree of agglomeration can enable the original dispersed manufacturing enterprises to realize the sharing of resources and information, and under the effect of scale effect and spillover effect, the pollution level can be reduced. When the level of agglomeration is between -1.7963 and -0.3225, the increase in the level of agglomeration will increase the environmental pollution. This is because at this stage, the pollutant emission is too much, and the negative externality of scale effect begins to appear, however production technology and pollutant treatment capacity have not been effectively improved. When the agglomeration level exceeds -0.3225, environmental pollution decreases with the increase of the level of agglomeration. At this stage, technological innovation improves resource utilization efficiency and pollutant treatment capacity. Simultaneously, the agglomeration tends to mature, forming a sound and reasonable circular economy system, also can better control environmental pollution.

Combined with the level of manufacturing agglomeration in the middle and lower reaches of the Yangtze River in 2017, Anhui, Hubei and Hunan are still in the second stage, that is, the increase in the level of manufacturing agglomeration will aggravate environmental pollution. Although the level of agglomeration in the manufacturing industry has been greatly improved, it is difficult to break through the bottleneck of technological innovation, and it is unable to effectively solve the negative effects brought about by the scale effect, resulting in the increase of pollution and the decline of environmental quality. The four provinces and cities of Jiangxi, Jiangsu, Shanghai and Zhejiang have entered the third stage, that is, the increase in the level of manufacturing agglomeration will reduce the degree of environmental pollution, and among them, the level of concentration in Jiangxi is close to the inflection point.

IV. Conclusion

Based on the environmental pressure model, this paper introduces industrial agglomeration variables and foreign direct investment variables, and establishes a panel regression model to empirically analyze the impact of manufacturing agglomeration on environmental pollution in the middle and lower reaches of the Yangtze River from 2008 to 2017. The empirical results show that there is an inverted “N”-type curve relationship between manufacturing agglomeration and environmental pollution. At present, the middle and lower reaches of the Yangtze River are located on both sides of the second inflection point of the curve. Among them, the agglomeration level of manufacturing industry in Anhui, Hubei and Hunan provinces increased with the aggravation of environmental pollution. However, the improvement of manufacturing agglomeration level in Jiangxi, Jiangsu, Shanghai and Zhejiang can alleviate environmental pollution to a certain extent. Therefore, in order to effectively promote the overall development of the middle and lower reaches of the Yangtze River, while constantly improving the level of manufacturing agglomeration, we need to strengthen the flow of talent, technology and other elements among the regions, so as to accelerate the breakthroughs in technological bottlenecks of the three provinces of Anhui, Hubei and Hunan which are in the second stages.

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