Analysis and Comparative Study of China's Urban Environmental Pressure Based on Material Resources

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Abstract: On the foundation of IPAT model framework, this paper calculates the environmental pressure based on material resources in Nanjing, Wuhan and Chengdu in China from 2008 to 2017, and analyzes the factors of population, affluence degree and technical level by log mean divisia index method to explore the direction and extent on environment. In general, demographic factors and affluence factors have an increasing effect on environmental pressure, and technological advances have a mitigating effect on environmental pressure. In different cities, due to other factors such as resource endowment and location, even if the economic aggregates are similar, the magnitude and extent of the factors considered in the model will be different, suggesting that the development of urban economy should be tailored to local conditions and promoting technology progress is a key issue.

1. Introduction

As a typical developing country, China has maintained a rapid and stable growth state based on a weak economic foundation through long-term efforts. During this period, the consumption of material resources and ecological environment is a prominent problem. Urban ecological environment is an important part of the economic system, and material resources are the basis and important guarantee for urban economic development. China's resource-based cities are numerous and widely distributed, which make a huge historical contribution and have outstanding realities. However, in the content of current international political and economic uncertainty and some other instability factors, the domestic economic development is unbalanced and uncoordinated. The internal and external risks are superimposed, and new and old contradictions are increasing. The sustainable development of China's urban resources faces severe challenges and the task of accelerating the transformation of economic development is very difficult. At the same time, the historical problems left by the resource-exhausted cities are still serious. The endogenous impetus of develop transformation are not strong. The dependence of industrial development on resources and environment is still heavy. Modern manufacturing and high-tech industries are in their infancy, the gathering ability of talents and funds and other factors is weak, the level of innovation is low, and the support for further development of alternative industries is seriously insufficient. New contradictions in resource-rich areas have emerged, and the pressure for sustainable development is greater. In some areas, the development intensity is too large and the level of comprehensive utilization of resources is low. The ecological environment is seriously damaged, and new geological disasters are constantly emerging. Low-level repeated construction of high-consumption high-pollution and high-emission projects is heavy, and the continuation of the development of alternative industries is weak. There are many contradictions in the distribution of interests caused by resource development, land acquisition and demolition, and the pressure on stability develop is high. The contradiction between resource development, economic and social development, and ecological environmental protection is uneven and uncoordinated.

In a certain sense, the research on the relationship between urban economic development and resource environment helps to coordinate the consumption of material resources, balance the symbiotic relationship between economy and environment, and maintain the good condition of social

development.

2. Literature review

The early theory of environmental Kuznets curve suggests that the economic growth will have a “U”-shaped effect on environmental pollution that first aggravation and then alleviation, then the subsequent research about the relationship between economic development and environment are more refined, and the research level is more in-depth.

In terms of the research methods used, Guo Hang, Jiang Yuan-sheng (2011) used the IPAT equation to study the factors affecting CO2 emissions. The regression results show that economic scale is the main factor, income and population are also the driving factors, and the technical level have a positive effect at the beginning time then due to the level increased have a negative effect in the later period.Cao Jie, Guo Chenglong, Zhou Yanqing (2018) used LMDI decomposition method to study the driving factors of industrial energy consumption in Nanjing. The results show that social wealth factor is the main driving factor for energy consumption growth, then followed by population, energy intensity but the economic structure is the inhibitors.

In terms of research objects, Wang Kai, Xia Lihui, Chen Qinchang, and Liu Haolong (2018) used the “bottom-up” method to calculate the tourism energy consumption and carbon emissions from 2001 to 2015 in China and then evaluate the dynamic trend of emission efficiency. The research shows that the spatial distribution of carbon emission efficiency in China's tourism industry is unbalanced, but the overall situation continues to rise. It points out that while relying on technological progress to improve carbon emission efficiency, all provinces should pay attention to the formation of global space linkage pattern. In the end, the coordinated development of low-carbon tourism will be realized.Yuan Jing and Li Zhiguo (2018) used the IPAT model and its structural decomposition method to quantitatively analyze the influence degree of various factors of urban spatial expansion in Yunnan Province, and obtained a series of realistic significant conclusions to solve the prominent contradiction between limited land resources caused by excessive expansion of urban space and social economic development of Yunnan Province through ridge regression.

In terms of the conclusions reached, Ding Weina, Marianna Gilli, Massimiliano Mazzanti, Francesco Nicolli (2016) used data from 95 provinces in Italy from 1990 to 2010 to study the relationship between energy-saving technologies and CO2 emissions and emission efficiency. Although energy-saving technologies have improved environmental productivity, they have not significantly improved environmental efficiency, and achieved the same results in different regions. Yu Yadong, Ma Tiezhen, Zhu Bing (2017) introduced the IPAT equation based on the calculation of Shanghai's 2010-2013 material footprint to specifically analyzed the environmental pressure and driving forces. The change of the ratio of individual resources has a non-negligible impact on environmental pressure. Population and affluence also have a promoting effect, and the improvement of the technical level has a mitigating effect. At the same time, relevant suggestions for reducing urban environmental pressure have been put forward.

3. Methods and data

The IPAT model was first proposed by Ehrlich and Holden (1971). It believes that the impact of human activities on the urban environment is caused by the combination of population(P), affluence degree(A) and technical level(T). According to the IPAT equation, the usage of material resources can be expressed as $MC = P \cdot A \cdot T = P \cdot \frac{GDP}{P} \cdot \frac{MC}{GDP}$.

Changes in environmental pressure measured by material resources can be expressed by changes in regional resident population, regional affluence which expressed in per capita GDP, and technical level T (=MC/GDP):

$$\Delta MC = MC^{t} - \mathrm{MC}^{0},$$

$$\Delta MC = \Delta MC_P + \Delta MC_A + \Delta MC_T$$

According to the log mean divisia index method, it can be expressed as

$$\begin{cases} \Delta MC_{\mathrm{p}} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \dfrac{MC_{\mathrm{i}}^{\mathrm{t}} - MC_{\mathrm{i}}^{0}}{\ln MC_{\mathrm{i}}^{\mathrm{t}} - \ln MC_{\mathrm{i}}^{0}} \ln \dfrac{P_{\mathrm{i}}^{\mathrm{t}}}{P_{\mathrm{i}}^{0}} \\ \Delta MC_{\mathrm{A}} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \dfrac{MC_{\mathrm{i}}^{\mathrm{t}} - MC_{\mathrm{i}}^{0}}{\ln MC_{\mathrm{i}}^{\mathrm{t}} - \ln MC_{\mathrm{i}}^{0}} \ln \dfrac{A_{\mathrm{i}}^{\mathrm{t}}}{A_{\mathrm{i}}^{0}} \\ \Delta MC_{\mathrm{T}} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \dfrac{MC_{\mathrm{i}}^{\mathrm{t}} - MC_{\mathrm{i}}^{0}}{\ln MC_{\mathrm{i}}^{\mathrm{t}} - \ln MC_{\mathrm{i}}^{0}} \ln \dfrac{T_{\mathrm{i}}^{\mathrm{t}}}{T_{\mathrm{i}}^{0}} \end{cases}$$

This paper mainly selects three cities Nanjing, Wuhan, and Chengdu which distributed in the eastern, central and western region of China for comparative research to study the changes in environmental pressure between 2008 and 2017. These three cities are the provincial capital cities of China, and they are also strong second-tier cities with similar economic strength and develop level. As far as the country is concerned, the speed and level of economic development of these three cities are relatively high. However, due to some historical and geographical factors, the focus of their development is not uniform, and the level of production technology is also different.

The material resources selected for the study include urban electricity usage, water usage, mineral resource usage (mainly include raw coal, oil and natural gas) and biomass resources usage (food and wood). The data are derived from the statistic yearbook of each city.

It can be seen from the data obtained that the usage of material resources in these cities is basically on the rise. The eastern coastal areas of China have strong economic bases and advanced production techniques. Relatively speaking, the more developed industrial city always uses more water resources such as Nanjing and Wuhan. The usage of electricity is relatively similar in three cities, and the latecomer Chengdu is in the upper reaches; the mineral resources and natural resources are richer in the central and western region than in the eastern region, Chengdu produce and export more natural resources and its primary processed products are more advanced.

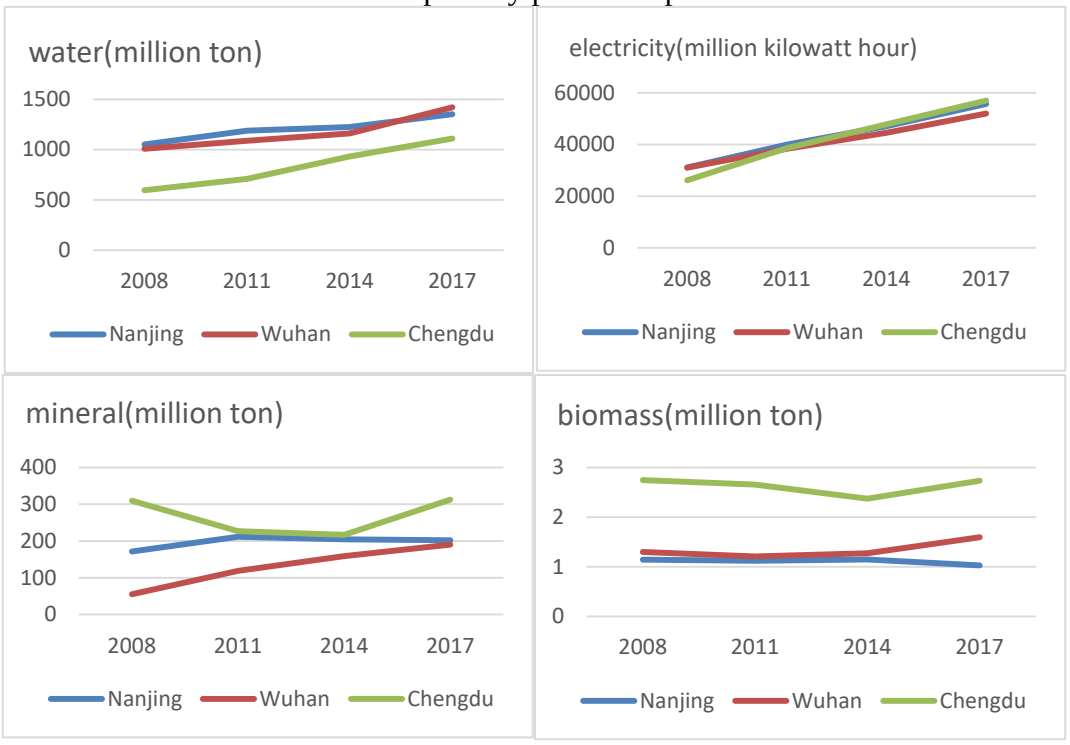

Fig. 1 Comparison of four material resources in three cities

According to our calculations, the environmental pressure measured by material resources and total production value are in a step-by-step manner, showing a state of growth. The technical level of

these three cities is gradually improve by the time, and the material resources consumed for producing GDP per dollar are declining. The city with the highest level of progress is Wuhan, and the central city has great technological upgrading potential; Chengdu did not show obvious technological progress until 2011 and then progressed.

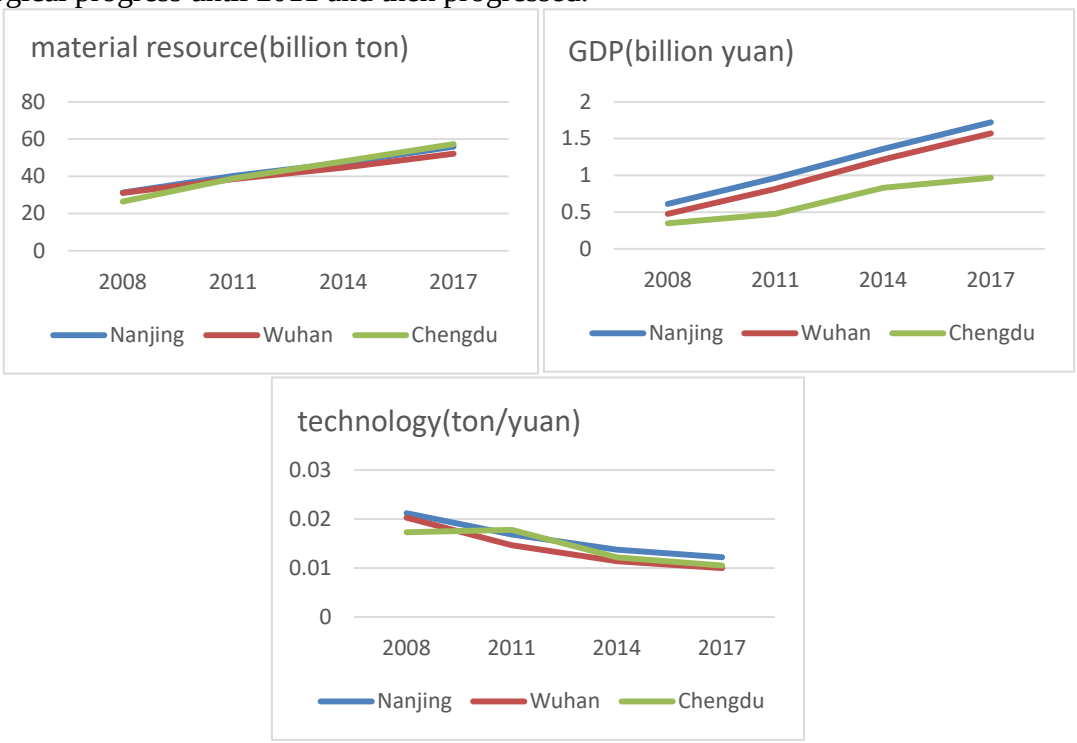

Fig. 2 Total urban material resources, GDP, and technical level in three cities

4. Results and discussion

From 2008 to 2017, the environmental pressure of Nanjing based on material resources increased from 3,323,048,800 tons to 572,091.4 million tons, an increase of 77.23%, and the per capita material resources increased from 5,173 tons to 8,411 tons, an increase of 62.6%; the environmental pressure of Wuhan increased from 320,914.57 million tons to 535,495.94 million tons, an increase of 66.87%. The per capita material resources increased from 3851.4 tons to 6,273 tons, an increase of 62.88%. The environmental pressure in Chengdu increased from 270,151,500 tons to 584,173.1 million tons, an increase of 116.24%, per capita material resources increased from 2401.4 tons to 4070 tons, an increase of 69.48%.

Compared with the environmental pressure based on material resources, during this period, Nanjing's GDP increased from 381.462 billion yuan to 117.51 billion yuan, an increase of 207.11%, and Wuhan's GDP increased from 396.08 billion yuan to 13410.334 billion yuan, increased 238.64%, Chengdu's GDP increased from 390.090 billion yuan to 138.889 billion yuan, an increase of 256.05%. In the decoupling theory proposed by Yu et al. (2017), economy developed but environmental pressure reduced is called absolute decoupling. If the rate of economy development is higher than the environmental pressure growth rate, it called relatively decoupled. The economic growth rate lower than the environmental pressure growth rate belongs to decoupling. From this point of view, the urban economic growth studied in this paper is relatively decoupled from the environmental pressure based on material resources.

According to the IPAT equation, the degree of contribution and contribution rate of population P, affluence degree A, and technical level T calculated by log mean divisia index method to urban environmental pressure changes based on material resources are shown in the following table.

Table. 1 Drivers of environmental pressure changes

2008-2011	△MC (million ton)	△P (million ton)	△A (million ton)	△T (million ton)	△P (%)	△A (%)	△T (%)
Nanjing	9072.69	689.53	16784.48	-8401.31	7.6	185	-92.6
Wuhan	7481.37	224.44	19301.94	-11596.13	-3	258	-155
Chengdu	12504.11	1250.41	10378.41	875.29	10	83	7
2011-2014	△MC (million ton)	△P (million ton)	△A (million ton)	△T (million ton)	△P (%)	△A (%)	△T (%)
Nanjing	7103.63	852.44	15343.84	-9092.65	12	216	-128
Wuhan	6270.57	0	16993.25	10722.68	0	271	-171
Chengdu	9433.62	1792.39	24433.07	-16791.84	19	259	-178
2014-2017	△MC (million ton)	△P (million ton)	△A (million ton)	△T (million ton)	△P (%)	△A (%)	△T (%)
Nanjing	8771.54	2631.46	12367.88	-6227.80	30	141	-71
Wuhan	7706.19	1541.24	12638.16	-6473.20	20	164	-84
Chengdu	9464.36	9085.79	8139.35	-7760.78	96	86	-82

The results of the decomposition method are analyzed in detail, In generally speaking, the population and affluence degree are the main factors for the increase of environmental pressure. Among them, the affluence degree is greater than the population factor. The advancement of technology level has a reducing effect on environmental pressure, and its effect is generally greater than the population but less than the factor of affluence degree. From 2008 to 2017, the effects of population, affluence degree and technical level on environmental pressure in these three cities have shown a trend of higher at beginning and lower at later time, which is consistent with the U-shaped effects reflected in many studies about the environmental impact of economic development. Specific to the city, although the GDP of these three cities are similar, the population and affluence degree of Nanjing have always been positive, while the technical level is negative and the state of development is relatively stable. Between 2008 and 2011 in Wuhan, demographic factors also have the effect of alleviating on environmental pressure, and then appear to aggravate environmental pressure, and the reasons may be associate with demographic factors. When there are more professional or high-quality talents among the people, it can produce environmental pressure reduction effects. The role of population factor in Wuhan may be due to the loss of talents. Professionals with high technology or high-quality labor flow to other regions, resulting in lower average quality of the population, which in turn increases environmental pressure. The technology level in Chengdu did not show the effect of reduction on environmental pressure during 2008-2011, but increased the resource consumption. The reason may be that as it located in the western region, which the overall technical level and production process are not as advanced as the central and eastern regions, that caused relatively backward effect on environment. Then the level of technology improved as the economy develop and showed the effect of reducing environmental pressure.

5. Conclusions and recommendations

On the foundation of IPAT model framework, this paper calculates the environmental pressure based on material resources in Nanjing, Wuhan and Chengdu in China from 2008 to 2017, and uses log mean divisia index method to analyze the effect direction and extent of population, affluence and technical level factors on environmental pressure. In general, demographic factors and affluence factors have an increasing effect on environmental pressure, and technological advances have a mitigating effect on environmental pressure. In different cities, due to other factors such as resource endowment and location, even if the economic aggregate is similar, the magnitude and extent of the factors considered in the model will be different. Specifically, the talents with professional skills in the demographic factors and high-quality labor may have a degrading effect on environmental pressure. Due to slower technology development in the western region, its environmental pressure will be affected accordingly.

Through the analysis and conclusions of this paper, we can get two inspirations for realizing the ecological balance and sustainable development of urban economy and environment. First, the economic development of the city should be adapted to local conditions, following certain social laws. Secondly, promoting technological innovation and improving the level of technology is the key words to achieve sustainable development.

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