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The impact of regional economic integration on CO_2 emissions in the Changsha-Zhuzhou-Xiangtan urban agglomeration, China

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ABSTRACT

The deepening of China's regional economic integration has posed potential impacts on climate change mitigation. This paper evaluates the impact of Changsha-Zhuzhou-Xiangtan economic integration policy on carbon emissions based on the total industrial output value, analyzes the correlation between carbon emission and total industrial output value of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014, and calculates the carbon dioxide emission per unit of industrial added value. The results show that under the influence of economic integration, the carbon dioxide emission per unit industrial added value of Changsha-Zhuzhou-Xiangtan urban agglomeration decreases significantly, and low-carbon industry gradually occupies a dominant position. The results are helpful for the design of carbon emission reduction path and the formulation of carbon neutralization long-term policy of Changsha-Zhuzhou-Xiangtan urban agglomeration.

Keywords: Carbon neutrality, spatial autocorrelation, correlation analysis

1. INTRODUCTION

According to the Sustainable Development Goals (SDGs), by 2030, nearly 60% of the world's population will live in urban areas. How to maintain the balance between economic development and ecological environment has become a rigid challenge for humankind [1,2,3]. In response to this situation, at the beginning of 2021, the Chinese government planned to establish and improve a green and low-carbon economic system based on efficient utilization of resources, strict protection of the ecological environment and effective control of greenhouse gas emissions, so as to reach the peak of carbon dioxide emissions by 2030, and achieve carbon neutralization by 2060 with the "double carbon" goal of carbon peak and carbon neutralization [4,5]. The mechanism and driving factors of carbon emissions have gradually become the focus of research in recent years.

Many researchers have discussed the relationship between carbon emissions and all aspects of the national economy, attempting to find a balance between economic development and carbon dioxide emissions [6]. Shi et al. [7] quantified and compared the CO_2 emissions from nighttime light images and socioeconomic data, confirming that the proportion of the secondary industry is the main factor affecting carbon dioxide emissions, GDP Urbanization rate and population play a more important role in prefecture level carbon dioxide emission. Liu et al. [8] evaluated the impact of different socio-economic development and urban spatial structure on carbon dioxide emission in Guangzhou through scenario simulation, and found that moderate population and economic growth, more technology investment and compact development of urban spatial pattern can effectively balance economic growth and carbon dioxide emission in Guangzhou. Chen et al. [9, 10] provided a broader perspective for the carbon impact of urban economic activities by constructing the technical framework and carbon metabolism evaluation index of virtual carbon metabolism modeling related to physical carbon and fossil fuel combustion in cities. Hu et al. [11] considered the urban carbon footprint from the perspective of production, consumption and trade balance, and pointed out that urban carbon emission reduction needs rational consumption and industrial symbiosis, e.g., cities with high consumption should change the

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consumption mode, while those with low production efficiency should improve production technology. In summary, most previous studies analyzed the relationship between urban economic activities and carbon dioxide emissions through finger model construction and scenario analysis, and put forward suggestions on the adjustment of urban economic development structure under the low-carbon goal.

Taking small-scale districts and counties as examples, this paper discusses the impact of economic integration policy on carbon emissions in 23 districts and county-level areas of Changsha Zhuzhou Xiangtan Urban Agglomeration, one of China's important urban agglomerations, from 2000 to 2014 by using spatial analysis and correlation analysis. By analyzing the relationship and development trend between regional industrial development and carbon emission in 23 districts and counties of Changsha Zhuzhou Xiangtan Urban Agglomeration [12, 13], we aim to provide a scientific basis for the future economic integration transformation and industrial structure adjustment of Changsha Zhuzhou Xiangtan Urban Agglomeration, thus aiding in the coordinated development model of ecology and economy of urban regional integration in China [14].

2. STUDY AREA

Changsha-Zhuzhou-Xiangtan Urban Agglomeration is located in the Middle East of Hunan Province, China. It is an important part of the urban agglomeration in the middle reaches of the Yangtze River, including Changsha, Zhuzhou and Xiangtan, 23 cities and regions [15] (see Figure.1). The total land area is 28,000 square kilometers, accounting for 13.34% of the province. The resident population accounts for 25.10% of the province (2020). The regional GDP accounts for 42.10% of the province (2020), Among them, Changsha is 1214.252 billion yuan, ranking the first in Hunan Province.

Figure 1 Administrative division of Changsha-Zhuzhou-Xiangtan urban agglomeration

Changsha-Zhuzhou-Xiangtan urban agglomeration is the core area of economic development and urbanization in Hunan Province, the transition zone between the eastern coastal area and the hinterland of the central and western regions, and the intersection zone of the Yangtze River open economic belt and the coastal open economic belt [16]. In 1997, Hunan Province established the provincial coordination organization for the economic integration development of Changsha, Zhuzhou and Xiangtan, and began to promote the integration of the three cities of Changsha, Zhuzhou and Xiangtan. In 2005, the "Tenth Five Year Plan" for economic integration of Changsha, Zhuzhou and Xiangtan was implemented [17]. In 2006, Changsha, Zhuzhou and Xiangtan Urban agglomeration was listed as one of the key urban agglomerations to promote the rise of central China. In recent years, Changsha-Zhuzhou-Xiangtan Urban agglomeration has further promoted economic integration, with the goal of establishing a new model of urban agglomeration with coordinated development of production, life and ecology [18].

3. MATERIAL AND METHODS

3.1 Material

The economic development data were sourced from the Hunan Statistical Yearbook， and the emission inventories were obtained from the China Emission Accounts and Datasets (www.ceads.net).(Figure.2)

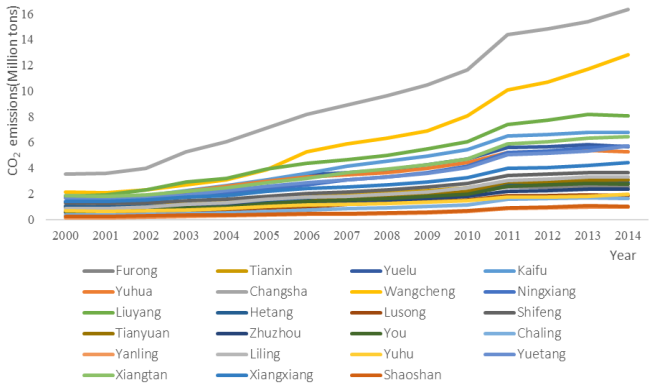

Figure 2 Changes of carbon emissions in districts and counties of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014

3.2 Methods

This study analyzes the spatial distribution pattern of carbon emissions in the districts and counties of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014 through spatial analysis [19]. Then, SPSS correlation analysis model is used to analyze the correlation between carbon emissions and total industrial output value in the districts and counties of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014, so as to obtain the impact of Changsha-Zhuzhou-Xiangtan economic integration policy on carbon emissions.

Pearson correlation coefficient is also used to judge the correlation between carbon emissions and total industrial output value of county-level areas in Changsha-Zhuzhou-Xiangtan Urban Agglomeration from 2000 to 2014. Correlation analysis is a conventional statistical method to study the correlation between two or more random variables in the same position. The value of Pearson correlation coefficient is - 1 to 1, corresponding to negative correlation and positive correlation, respectively. The closer the absolute value of Pearson correlation coefficient is to 1, the stronger the correlation is. When the significance p value is < 0.05, there is a significant difference between these two. Here the correlation analysis is conducted by SPSS software.

We also calculated the carbon dioxide emissions per unit of industrial added value in each district and county-level area of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014, which is obtained by dividing the carbon emissions of that year by the total industrial output value that is used to measure the development degree of low-carbon industry in the study area. The calculation formula is as follows:

$$X=C/IND \quad (1)$$

Where, X is the carbon dioxide emission per unit of industrial added value, with the unit being ton / 10000 yuan; C is the carbon emission of the study area, in tons; IND is the total industrial output value of the study area with the unit of 10000 yuan.

4. RESULT

4.1 Correlation analysis

This paper analyzes the correlation between carbon emission and total industrial output value in each district and county-level area of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014. According to the analysis results (Table 1), the Pearson correlation coefficients between carbon emissions and total industrial output value in all districts and county-level areas of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014 are close to 1, and P < 0.001, i.e., there is an extremely significant correlation between them at the level of 0.01.

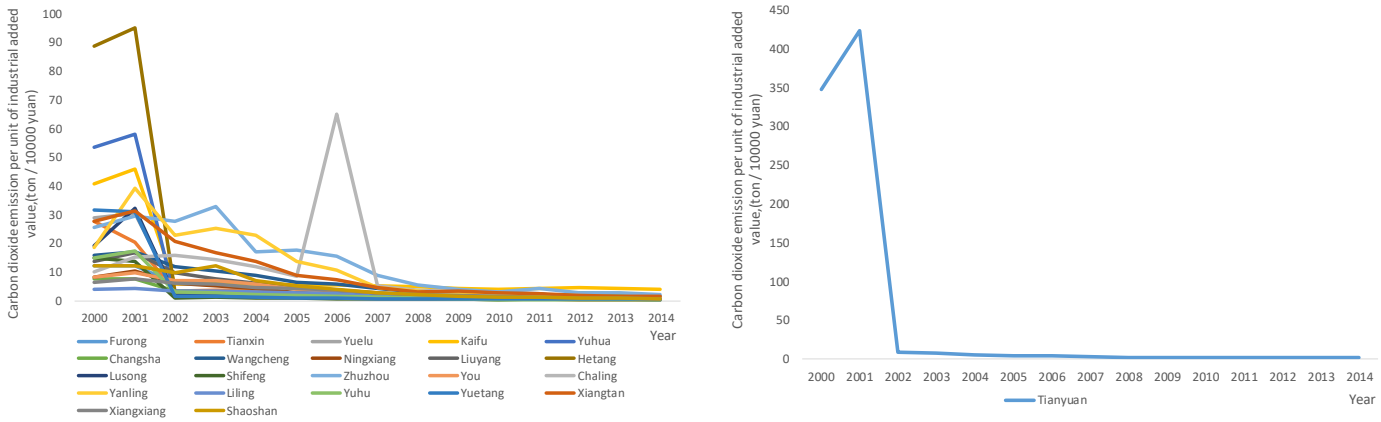

Figure.3 Carbon dioxide emissions per unit of industrial added value in districts and county-level areas of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014 (Because the initial result of Tianyuan District is too large, make a separate figure replace.)

Table 1 Correlation analysis results

Area	Pearson correlation coefficient	*P* value
Furong	0.960	0.000
Tianxin	0.972	0.000
Yuelu	0.951	0.000
Kaifu	0.985	0.000
Yuhua	0.962	0.000
Changsha	0.836	0.000
Wangcheng	0.823	0.000
Ningxiang	0.950	0.000
Liuyang	0.914	0.000
Hetang	0.967	0.000
Lusong	0.965	0.000
Shifeng	0.970	0.000
Tianyuan	0.974	0.000
Zhuzhou	0.928	0.000
You	0.974	0.000
Chaling	0.930	0.000
Yanling	0.958	0.000
Liling	0.956	0.000
Yuhu	0.940	0.000
Yuetang	0.984	0.000
Xiangtan	0.963	0.000
Xiangxiang	0.951	0.000
Shaoshan	0.962	0.000

The calculation results of carbon dioxide emissions per unit of industrial added value in each district and county-level area of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014 are shown in Figure 3.

According to the calculation results, the carbon dioxide emissions per unit of industrial added value in each district and county-level area of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014 generally showed a downward trend year by year.

4.2 Spatial analysis

Based on the known significant correlation between carbon emission and gross industrial output value of all districts and counties of Changsha-Zhuzhou-Xiangtan Urban Agglomeration from 2000 to 2014, through spatial visualization of carbon emission changes of all districts and counties of Changsha-Zhuzhou-Xiangtan Urban Agglomeration from 2000 to 2014 (Figure. 4), it is found that the carbon emission trend of all districts and counties of Changsha-Zhuzhou-Xiangtan Urban Agglomeration from 2000 to 2014 shows similar upwards trends, including Changsha County, Wangcheng County From 2000 to 2014, of which the added value of carbon emissions in three regions of Liuyang City was the largest, the added value of carbon emissions in Yanling County of Zhuzhou City and Shaoshan City of Xiangtan city was the smallest, and the growth of carbon emissions in all districts and counties of Changsha City was significantly higher than that in Zhuzhou City and Xiangtan City; Taking the average value of the change value of carbon emissions from 2000 to 2014 in all districts and counties of Changsha-Zhuzhou-Xiangtan urban agglomeration and calculate the difference between them and the average value

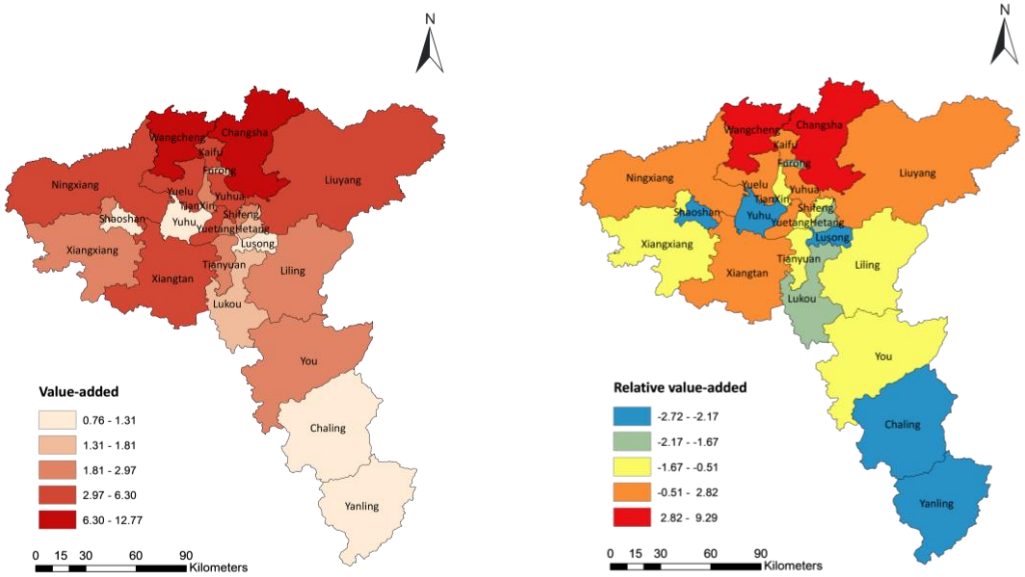

Figure.4 The value added and the relative value added of carbon dioxide emissions of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014

(Figure. 4), it is found that the growth value of carbon emissions in most areas is lower than the average level, and the growth value of carbon emissions in Changsha County and Wangcheng County of Changsha City is far ahead of the average level. Based on the above analysis, it can be concluded that Changsha is a major carbon emitter in the Changsha-Zhuzhou-Xiangtan urban agglomeration, which is also a major industrial developed area, and its economic development level is the highest among the three cities.

5. DISCUSSIONS AND CONCLUSION

China is in an important transition of economic development that can not be at the cost of destroying the ecological environment [20]. Through the correlation analysis, it is found that there is a significant correlation between carbon emissions and total industrial output value in all districts and county-level areas of Changsha-Zhuzhou-Xiangtan urban agglomeration from 2000 to 2014, i.e., industrial production has a great impact on carbon emissions of Changsha-Zhuzhou-Xiangtan urban agglomeration. To achieve the low-carbon goal of Changsha-Zhuzhou-Xiangtan urban agglomeration, we need to deal with industrial production, especially rectify high polluting industries and promote clean energy utilization. In addition, the carbon dioxide emissions per unit of industrial added value in all districts and county-level areas of Changsha-Zhuzhou-Xiangtan urban agglomeration decreased year by year from 2000 to 2014, indicating that the economic integration of Changsha-Zhuzhou-Xiangtan urban agglomeration has promoted the development of low-carbon industry, i.e., on the whole, the carbon emissions of Changsha-Zhuzhou-Xiangtan urban agglomeration are greatly affected by industrial production. However, under the influence of economic integration, the total industrial output value of Changsha-Zhuzhou-Xiangtan urban agglomeration has increased significantly, Meanwhile, the carbon dioxide emission per unit of industrial added value decreased, i.e., low-carbon industry gradually occupied a dominant position in the industrial production of Changsha-Zhuzhou-Xiangtan.

This study has some limitations. First, the evaluation of economic integration in Changsha, Zhuzhou and Xiangtan only considers the total industrial output value without considering the socio-economic indicators such as per capita GDP, population flow and per capita income. Thus the evaluation of economic integration in Changsha, Zhuzhou and Xiangtan may not be comprehensive; Secondly, this paper only obtains the correlation between total industrial output value and carbon emission, and does not further explore the driving factors of carbon emission of Changsha-Zhuzhou-Xiangtan urban agglomeration. Finally, the discussion on the spatial distribution of carbon emission of Changsha-Zhuzhou-Xiangtan Urban Agglomeration is simple and needs further investigation because regarding the integration planning of Changsha-Zhuzhou-Xiangtan Urban Agglomeration, the aggregation, transfer and flow of carbon emission centers have important reference value for the mechanism and influencing factors of carbon emission , and contribute to the realization of double carbon objectives and policy planning of Changsha-Zhuzhou-Xiangtan Urban Agglomeration.

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