Collaborative Governance Mechanism of Carbon Neutralization and High Quality Development in Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract. At present, China is in the stage of rapid economic development. The construction of high-tech and urban agglomeration is inevitable, which directly leads to the increase in carbon dioxide emissions. Under the international background, the strategic goal of ' carbon neutrality ' proposed by the national government is still imminent. Therefore, how to control carbon dioxide emissions is urgently needed. This paper focuses on the urban agglomerations of Guangdong, Hong Kong, and Macao. Through the kaya equation and STIRPAT model, the factors that significantly affect the Greater Bay Area are screened and tested. Through the analysis, the corresponding countermeasures are put forward for the timely mitigation and reduction of carbon emissions in Guangdong, Hong Kong, and Macao. At the same time, it aims to explore a feasible path for other urban agglomerations in China.

Keywords: Guangdong-Hong Kong-Macao Greater Bay Area; carbon emissions; carbon neutralization; iPAT; sTIRPAT

1. Introduction

The concept of carbon neutrality emerged in the European region in the 2000 s and gradually attracted the attention of governments. In 2016, the Paris Agreement was formally implemented and 197 (more than 175) countries became parties, contributing to a new trend in global climate governance in the future. It is expected to achieve global carbon neutrality between 2051 and 2100 while keeping the global average temperature rise below pre-industrial levels within 2 degrees Celsius and working to keep the temperature rise below 1.5 degrees Celsius.

" Dual carbon policy " is becoming one of the biggest driving forces for China's economic transformation and development. At present, carbon neutralization has become an urgent problem to be solved by our government, enterprises, people's livelihood, and the world. On the issue of carbon neutralization, IThe country has issued a series of documents. In 2016, the 13th Five-Year Plan issued relevant regulations and implementation rules, proposing the establishment of a national carbon emission trading system, the establishment of national and local management systems, the improvement of departmental coordination mechanisms, and the implementation of carbon emission quota management systems. In 2017, the ' National Carbon Emissions Trading Market Construction Programme (Power Generation Industry) ' was issued and implemented, calling for a unified national carbon emission trading market. In 2020, the 14th Five-Year Plan proposed to fully implement the emission permit system and promote market-oriented trading of emission rights, energy rights, water rights, and carbon emission rights. In September 2020, Xi Jinping put forward the 3060 targets during the 75th United Nations General Assembly, that is, carbon peak in 2030 and carbon neutralization in 2060. In December 2020, the Ministry of the Ecological Environment issued the ' Carbon Emission Trading Management Measures (Trial) ' in the form of a decree, including General Provisions (1-7) Distribution and Registration of Key Greenhouse Gas Emission Units (8-13) (14-19) Emission Trading (20-24) Emission Verification and Quota Payment (25-29) Supervision and Management (30-36) Penalty (37-41) Supplementary Provisions (42-43). In July 2021, the national carbon emissions trading market was officially launched, and more than 2000 power generation companies were included in the national market. At present, the national carbon emission rights registration and settlement center were established in Hubei, and the trading center was established in Shanghai Environmental Exchange.)

As one of the regions with the highest density and vitality of China's economic construction, promoting carbon neutrality in the Guangdong-Hong Kong-Macao Greater Bay Area has increasingly become an important measure to promote China's high-quality economic development and respond to global climate problems and environmental crises. The annual research report on carbon neutralization in Guangdong-Hong Kong-Macao Greater Bay Area in 2021 shows that the carbon emissions per unit GDP and per capita carbon emissions in the Guangdong-Hong Kong-Macao region are better than those in the Yangtze River Delta and Beijing-Tianjin-Hebei region. Among them, Hong Kong has allocated 47 billion yuan over the past decade to implement energy-saving and renewable energy measures, promote electric vehicles and ships, introduce innovative waste-to-energy and waste-to-material facilities, and help reduce waste and carbon. The 2020 policy report notes that Hong Kong's carbon emissions peaked in 2014, with a view to achieving carbon neutrality by 2050; Macao Environmental Protection Agency also pointed out that in recent years, carbon emissions have entered the peak fluctuation range of carbon emissions; tang Jie, former deputy mayor of Shenzhen and professor of economics and management at Hagong University (Shenzhen), pointed out in December 2020 that Shenzhen was in a stable peak period between 2019 and 2020; Guangzhou pointed out in 2017 that by the end of the 13th Five-Year Plan period, the city's industrial structure and energy consumption structure had been further optimized, energy efficiency had been continuously improved, energy consumption and total carbon emissions had been effectively controlled, and the peak of total carbon emissions had been achieved. In 2019, the added value of the advanced manufacturing industry in Guangzhou and Shenzhen accounted for 58.4 % and 71.9 % respectively. The implementation of the " dual carbon policy " in the Guangdong-Hong Kong-Macao Greater Bay Area has continuously eliminated the production capacity with heavy pollution and high emission, and the industrial structure has been optimized. High-tech manufacturing accounts for a high proportion.

China has repeatedly stated that it will strive to reach the carbon peak by 2030 and achieve carbon neutrality by 2060. At present, the debate is still focused on how to adjust the energy structure, promote industrial facilities, improve carbon emission detection indicators, improve the evaluation mechanism of provinces and cities, build an emission reduction policy system, implement system and capacity building, and accelerate the formation of enterprise green production and residents ' lifestyle ecological circle to achieve the synergistic effect of reducing pollution and reducing carbon, so as to achieve the goal of carbon neutralization, which is a problem that must be solved in China's exploration of carbon neutralization. Therefore, the research on this topic is very urgent and has certain practical significance. This paper takes carbon neutrality as the core and Guangdong-Hong Kong-Macao Greater Bay Area as the research object, aiming to explore the methods suitable for urban agglomerations to achieve carbon neutrality by using the correct methods, including establishing the detection index system, exploring the influencing factors of carbon neutrality and proposing improvement measures and solutions to accelerate the process of carbon neutrality and the maintenance of urban agglomerations, and enlightening other urban agglomerations on measures and principles.

2. Literature review

In recent years, scholars have deepened their understanding of the current situation of carbon emissions, and carried out fruitful research on the influencing factors of carbon emissions and the implementation path of carbon neutralization. Theoretical circles mainly use the general equilibrium method, econometric analysis method, and exponential decomposition method to detect the influencing factors of urban carbon emissions. The general equilibrium method can analyze the impact of industrial structure and environmental policy plan through the input-output table data, but the data comes from the table and there is data lag. The quantitative analysis method can be flexible empirical, overcome the problem of time series, and the measurement method is simple, but can only explain the monotonic relationship; exponential decomposition is the most widely used method, but it ignores time series, regional heterogeneity, technological capital progress, and other factors, and cannot explain the nonlinear relationship between influencing factors and carbon emissions. In summary, there are different ways, which need to be determined according to the actual situation of measurement and the development trend of urban agglomeration. Taking the exponential decomposition method as an example, Tang et al. believed that per capita income level and urban population are the two most important factors affecting carbon emissions by constructing the STIRPAT model and the autoregressive moving average model (ARMA). Zhang Chenlu and other studies suggest that ecological protection and industrial structure upgrading have a practical impact on carbon emissions; and Miao Jianjun and other research highlights the second, three industrial chain aggregation degree of carbon emissions from the promotion to inhibition ' inverted U ' type characteristics. In terms of the implementation path of carbon neutralization, Zhang Haonan et al. believed that it was necessary to rely on the strong support of policy mechanisms and the effective cultivation of the market environment, and adopt high electrification and carbon capture driven by new energy based on energy efficiency technology. The negative emission supported by technology is a feasible and affordable comprehensive carbon neutralization scheme with deep emission reduction means and complementary integration of multiple low carbon technologies. Gao Weijun believes that in order to achieve carbon neutrality, Japan takes corresponding measures from top to bottom and from bottom to top in housing, construction, new energy, machine building materials, institutional equipment, and other programs. Jie et al. believed that the significance of integrating the green buildings into urban sustainable development was analyzed from the perspective of carbon neutralization, the problems existing in the planning and design of the urban green buildings were considered, and the ways to improve the design quality in urban green planning and construction were put forward.

The above research explores the influencing factors of carbon emissions and the effective ways to solve carbon neutrality, reveals the current industry law in China, and has an important guiding role in exploring the road of carbon neutrality. However, due to the research period, research area, research purpose and research methods are different in the conclusion. However, there are few studies on the influencing factors of carbon emissions and carbon neutralization approaches based on the development of urban agglomeration in Guangdong-Hong Kong-Macao Greater Bay Area. Therefore, this paper will take Guangdong-Hong Kong-Macao Greater Bay Area as the research object, analyze the temporal and spatial effects of carbon emissions, analyze the laws and explore a feasible path for society, government, enterprises and people 's livelihood.

3. Research on Influencing Factors and Methods of Carbon Emissions

In this paper, STIRPAT model is used to establish regression equation by IPAT. IPAT equation is used to analyze a large number of relevant influencing factors, including environmental impact, population size, technical level, richness, population size, per capita income level, energy structure, industrial structure and education level. Most researchers use this equation to study the relationship between environment, population, technology and economy. The equation is : $I = P \times A \times T$ where I represents environmental load, P represents population size, A represents wealth per capita GDP, T represents technology level. Based on the IPAT model, York et al. constructed the STIRPAT model, which is expressed as : $I = a \times Pb \times Ac \times Td \times e$, where a is a constant ; b, c and d represent the exponential elasticity coefficients of P, A and T, respectively ; e is the error term. STIRPAT model is the derivative of IPAT model. When $a = b = c = d = e = 1$, STIRPAT model is the IPAT equation.

(1) Index model analysis

After reading a large number of literature, the author concluded that carbon emissions from the national or regional population, per capita income level, energy structure, industrial structure and education level showed a significant indigenous correlation. Based on the STIRPAT model, according to the IPAT equation quantitative indicators, namely: I = a × Pb × Ac × Td × e, the researchers take out the natural logarithm on both sides of the equation, aiming to decompose the carbon emissions method into several quantitative indicators: population, per capita income level, energy structure, industrial structure and education level.

(2) Model formula explanation

Calculation of carbon emissions :

$$CE = (CE_1 \times y_1 + CE_2 \times y_2 + CE_3 \times y_3) \times (44 \div 12) \tag{1}$$

CE represents the total carbon emissions of a city. CE1, CE2 and CE3 represent the annual power consumption (kWh), total petroleum gas consumption (tons) and total natural gas consumption (cubic meters) of a particular city, respectively. y1, y2 and y3 represent the carbon emission coefficients of power grid, liquefied petroleum gas and natural gas, respectively ; 12 and 44 refer to the molecular weights of carbon and carbon dioxide, respectively. According to the method of Ding et al. (2020) in the authority, because urban electricity consumption and residential energy are the main sources of urban carbon emissions, and residential energy consumption mainly comes from liquefied petroleum gas and natural gas. Therefore, urban electricity consumption, liquefied petroleum gas and natural gas carbon emissions are selected as the main research objects, and the results obtained by this method are the carbon emissions of a city. Since the research objects of this paper are Hong Kong, Macao, Shenzhen, Guangdong and Zhuhai, this paper sums up the total carbon emissions of five cities and calculate the average as follows:

$$C = \frac{\sum CE}{5} \tag{2}$$

(1) Data sources

The data in this paper comes from the Statistical Yearbook of China Statistics Bureau. The annual data of urban power consumption, total consumption of liquefied petroleum gas and total consumption of natural gas are taken from China Energy Statistical Yearbook and China City Statistical Yearbook from 2006 to 2021. The urban electricity carbon emission factor is derived from the grid baseline emission factor in the official grid announcement of China, while the LPG and natural gas carbon emission factors are derived from 2021‘ Study on urban greenhouse gas inventory ’.

(2) Model analysis

The regression model was verified by SPSSAU14.0, and the five independent variables were population, per capita income level, energy structure, industrial structure and education level, respectively. All the five variables were tested by t test, which showed that they had significant effects on total carbon dioxide emissions. The model test results are shown in Table 1, where the p value of the corrected goodness of fit R2 is less than 0.001, which verifies that the fitting degree of this model is relatively good. At the same time, the measured DW value is 1.539, indicating that the correlation of this model is small.

Table 1. Model checking table

model	goodness of fit r	Modified goodness of fit	f test	F test p-value	DWtest
1	0.856	0.832	28.789	.000	1.796

Table 2. Independent variable test and regression coefficient table

model	regression coefficient	t-test	P-value	multicollinearity		
	coefficient	standard deviation			Tolerance	VIF
population size	2.637	4.134	4.420	0.000	0.328	1.548
industrial structure	0.434	1.227	2.468	0.000	0.185	1.574
energy efficiency	0.556	-0.184	3.523	0.000	0.579	1.367
level of education	1.919	3.343	5.435	0.000	0.574	1.084
per capita income	-0.329	0.713	-3.437	0.000	0.279	1.328
constant term	-8.645	2.850	-9.535	0.000		

According to the above data, the number of population, per capita income level, energy structure, industrial structure and education level all have impacts on carbon emissions in the Guangdong-Hong Kong-Macao Greater Bay Area. Among them, the number of population, education level and energy efficiency have the most significant impacts. The increase in population, education level and energy efficiency will lead to an increase in carbon emissions, and only the increase in per capita income will inhibit the content of carbon emissions.

4. A pathway to carbon neutrality in the Guangdong-Hong Kong-Macao Greater Bay Area

4.1 Optimizing the energy mix

Promote an energy supply system based on clean energy and electricity to help achieve the "double carbon" target. According to relevant statistics, fossil energy accounts for 85% of China's primary energy and 9.8 billion tonnes of carbon emissions per year, accounting for nearly 90% of the total carbon emissions of the whole society, while carbon emissions from fossil energy account for about 70% of all carbon emissions in the Greater Bay Area. With a high concentration of population and rapid economic development, the Guangdong-Hong Kong-Macao Greater Bay Area has a huge energy demand and is a typical energy input area. Therefore, optimizing and transforming the energy mix is a key part of achieving carbon neutrality. In addition, the development of promoting clean energy can also promote the rise of the carbon price by increasing the cost of energy conversion and raising the market development expectation of emission control enterprises, which will ultimately affect the cost of carbon emissions.

4.2 Optimizing the industrial structure

The Guangdong-Hong Kong-Macao Greater Bay Area has a high proportion of low-end industries, a large stock of high-energy-consuming and high-emission industries, which is still a manufacturing-heavy area with a high-carbon production structure that is difficult to change in the short term. Therefore, there is a need to support green industries on all fronts in terms of economy and policy, and to increase support for green industries, thereby attracting more entrepreneurs to develop new energy fields; promote the green transformation of the chemical industry, and place greater emphasis on technology-based enterprises to guide the direction of their development.

4.3 The vigorous development of education and science and technology

The Guangdong-Hong Kong-Macao Greater Bay Area relies on developed countries for key technologies, core component devices and materials and has made slow progress in the development and application of key energy technologies. Therefore, it is important to promote technological advancement, facilitate industrial structure upgrading, break through the technological window for curbing carbon emissions, and actively incubate and apply innovations to improve labor productivity and resource utilization for lower energy consumption and carbon emissions reduction.

4.4 Building a Carbon Emissions Trading System and a Carbon Trading Pricing Mechanism

Building a carbon emissions trading system and a carbon pricing mechanism is an important element in achieving high-quality development in the Guangdong-Hong Kong-Macao Greater Bay Area. It is important to create a policy environment that is in line with the goal of carbon neutrality, encourage low-energy enterprises to participate in carbon trading, form an institutional mechanism that is compatible with the development of clean energy, build a collaborative mechanism of "government-market-enterprise-residents" to reduce emissions, cultivate the awareness of energy conservation and emission reduction in the whole society, and create a carbon-neutral community of destiny.

5. Conclusion

Carbon emission is a difficult problem that the world needs to face. Therefore, it is necessary for scholars to further study, accurately locate the influencing factors and put forward practical improvement measures according to the phenomenon, so as to contribute wisdom to solving the world’s problems. The research on carbon emissions has been continuously promoted in the academic circle, but there is little research on the specific situation of carbon emissions in the Guangdong-Hong Kong-Macao Greater Bay Area. By focusing on the current situation of carbon emissions in the Greater Bay Area, the author finds out the obvious indigenous factors affecting carbon emissions, and puts forward suitable solutions combined with questionnaires and visiting scholars, which can also provide feasible experience for other urban agglomerations. In this paper, the IPAT equation is mainly used in the research process, and the data are collected through the official website. However, there are deficiencies in the time linearity. There is a discussion on eliminating the influence of time factors, which will be described in another paper.

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