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A Study on Influence Factor & Peak Value of Province Area in Developed Urban Agglomeration—Based on Tapio Decoupling & Panel Data Lag Tool

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Abstract— *The carbon emission of developed urban agglomeration in China is weak decoupling, its influence factors of seven provinces/cities in developed urban agglomeration are revealed by panel data lag tool which including industrial structure optimization, energy structure adjust and education level. The result shows that there do exist an environmental Kuznets inverse U curve between seven provinces/cities average per person GDP and carbon emission. There is an offset effect of industrial structure optimization to carbon emission: industrial structure promotion increase the carbon emission while industrial structure rationalization decrease it. Energy structure increase the carbon emission while education level decrease it. Hebei province is the key role in control the carbon emission and its peak value as Hebei has fastest growth carbon emission in seven provinces/cities.*

Keyword— *Carbon emission; Tapio decoupling; EKC curve; Peak value; Lag tool*

I. INTRODUCTION

China economy has put more emphasis on speed and quality simultaneously after the concept of "new normal" was put forward, constantly reforming and upgrading the industrial structure. The energy planning is one of the key point in the "13th Five-Year "plan, which focusing on controlling the total energy consumption, using coal cleanly and efficiently, developing clean energy vigorously and reforming energy system. It is expected to make contributions to the global energy conservation and emission reduction through the next five-year plan.

The Yangtze River Delta, the Pearl River Delta and the Jing-Jin-Ji region are the three traditional urban agglomerations. As of the end of 2018, the Yangtze River Delta including Jiangsu Province, Zhejiang Province and Shanghai, which GDP accounted for about 18.89% of the country; GDP of the Pearl River Delta accounted for about 10.08%, which only calculate Guangdong Province; Jing-Jin-Ji accounted for about 6.33% that is the the largest urban agglomeration in the north of China, including Beijing, Tianjin and Hebei Province. The energy consumption of these three major urban agglomeration accounts for about 30%[1]. These seven provinces/cities of the agglomerations are chosen to analyze the factors of carbon emission, which will help to develop a reasonable energy saving and emission reducing policy while promoting the better and faster development of the national economy.

II. LITERATURE REVIEW

Tapio elasticity coefficient method is widely used in the calculation of the relationship between economy and carbon emissions. It is frequently used to measure the correlation between economic growth and carbon emissions in an industry. Gao etc (2012) [2], Tang etc (2014) [3], Wang etc (2016) [4] respectively measured the decoupling effect between the power industry in Jiangsu Province, transportation and tourism in China. The decoupling index is also applied to analyze the decoupling effects between regional development and carbon emissions. Zhang etc (2013) [5], Zhou etc (2016) [6], Vavreka etc (2016) [7], Chen etc (2016) [8] respectively performed quantitative evaluation on the relationship between economic development and production of GHG emissions based on decoupling model theory in Jiangsu Province, China provinces and V4 region (Czech Republic, Hungary, Poland and Slovakia). In addition, some scholars combine this approach with other methods to study more macro-problems. Chen etc(2015)[9] used multi-parameter income distribution function and decoupling theory to investigate rural poverty in China. Alises etc (2015)[10] proposed an Input–Output structural decomposition analysis to explain road freight transport in terms of a set of key factors. Ren etc（2013）[11]、Zhao etc（2016）[12]、Ma etc（2016）[13]and Zhao etc（2016）[14] adopted the Log Mean Divisia Index(LMDI) method based on the extended Kaya identity to investigate the decoupling effect of economic growth from CO_2 emissions of Chinese manufacturing industry, industry, household and Industrial structure.

It can be seen that the combination of Tapio elasticity coefficient is very common, but there are few lagging tools that combine panel data to carry out regional comparison research results, however, panel data is also an important tool to study carbon emissions. Du etc.（2012）[15]、Zhou etc.（2016）[16] and Xu etc. （2016） [17] investigated the carbon dioxide emissions of driving forces, population and income, the quality of land based on a provincial panel data. Panel data is particularly suitable for cross regional comparative analysis, Wang etc. (2014) [18], Usama Al-mulali (2014) [19], Zakarya etc. (2015)[20] provided empirical evidence on the impact of economic growth and energy use on carbon emissions for municipalities directly under the central government, 30 major nuclear energy consuming countries, the BRICS countries. In recent years, there is also a trend of combining panel data with EKC model. Ozcan (2013) [21], Kang etc (2015) [22], Zoundi (2016) [23] examined the CO2 EKC hypothesis of different regions using a spatial panel data model. Furthermore, a comparative analysis of the turning points between the non-spatial panel model and spatial panel model is conducted.

In summary, current researches on the relationship between carbon emissions and economic growth are in lack of the following aspects: first, the methods chosen are not fit enough, generally, decoupling elastic coefficient method and the impact factor decomposition analysis method can only be used for time series analysis, which cannot reflect the horizontal relationship between regions. Granger cannot solve the endogenous problem between economic growth and carbon emissions. Second, the use of lagging tool to solve panel data endogenous problems in this area is still less, not taking into account the impact of previous of economic growth on current carbon emissions. Thirdly, there are still less research on seven provinces/cities which play a demonstration effect in the process of emission reduction.

III. MATERIALS AND METHODS

3.1 Date Resource

This paper estimates the carbon emission data of seven provinces/cities based on fossil fuels, including raw coal, coke, crude oil, gasoline, diesel, kerosene, fuel oil and natural gas, the carbon emission standard factor is coming from IPCC (2006). All data were collected from China Statistical Yearbook 2001-2017, China Energy Statistical Yearbook 2001-2017 and China Statistical Yearbook of High Technology Industry (2001-2017). The economic data in 2000 is chosen as the base year.

3.2 Tapio

Tapio elastic coefficient method overcomes the choice problem of base period in OECD, selecting the fixed year as the base year and calculating the decoupling index yearly. Based on decoupling criteria proposed by Tapio Petri, select 0.8 for the critical point[24]. Thus, eight logical possibilities are formed to distinguish the decoupling states, as shown in Table 1.

TABLE 1. The states and detail explanations of Tapio decoupling model.

State		ΔCO_2	ΔGDP	Range
Connection	Recessive connection	＜0	＜0	（0.8,1.2）
	Expansive connection	＞0	＞0	（0.8,1.2）
Decoupling	Recessive decoupling	＜0	＜0	（1.2，+∞）
	Strong decoupling	＜0	＞0	（-∞，0）
	Weak decoupling	＞0	＞0	（0,0.8）
Negative decoupling	Weak negative decoupling	＜0	＜0	（0,0.8）
	Strong negative decoupling	＞0	＜0	（-∞，0）
	Expansive negative decoupling	＞0	＞0	（1.2，+∞）

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In order to fully reflect the relationship between economic growth and carbon emissions, this paper uses three indicators of total carbon emissions (TCO_2), per capita carbon emissions (PCO_2) and carbon emission intensity (GCO_2). Economic growth and carbon emission decoupling index formula as shown in equation (1):

$$e_1 = \frac{\%TCO_2}{\%GDP} = \frac{(TCO_{2,\ t} - TCO_{2,0}) / TCO_{2,0}}{(GDP_t - GDP_0) / GDP_0}$$
$$e_2 = \frac{\%PCO_2}{\%GDP} = \frac{(PCO_{2,\ t} - PCO_{2,0}) / PCO_{2,0}}{(GDP_t - GDP_0) / GDP_0}$$
$$e_3 = \frac{\%GCO_2}{\%GDP} = \frac{(GCO_{2,\ t} - GCO_{2,0}) / GCO_{2,0}}{(GDP_t - GDP_0) / GDP_0} \quad (1)$$

In the formula,$\%TCO_2$, $\%PCO_2$, $\%GCO_2$ represent the total carbon emission, the per capita carbon emission and carbon intensity increase from the base period to the reporting period, t is the reporting period, and 0 is the base period.

3.3 Environmental Kuznets Curve

According to the assumptions of the Environmental Kuznets Curve (EKC), economic growth is accompanied by an increase of environmental pollution and energy consumption, but fewer environmental and energy consumption can be realized with new technologies or effective policy instruments which process is decoupling. EKC reveals that environmental quality deteriorates with economic growth, but when economic growth reaches a certain level, environmental quality improves with economic growth, that is environmental quality and economic growth are inverted U-type relationship. we extend EKC model as fol-lows:

$$\ln c_{it} = \alpha_1 (\ln y_{it})^2 + \alpha_2 \ln y_{it} + X_{it}\beta + \delta_t + \eta_i + \varepsilon_{it} \quad (2)$$

Where i is the area cross-section unit, 1= 1, 2, 3, t is the year; c_{it} means the total carbon emission or carbon intensity; y_{it} stands for the per capita GDP of each region; δ_t refers to the non-observational effect, including energy policy, energy-saving technology and so on;η_i represents regional non-observation effect, such as resource endowments and industrial patterns; ε_{it} is the standard error term; X is other control variables, selecting education level, advanced industry, industrial rationalization, regional openness, energy structure and innovation ability.

Education level, which will affect the industrial model and consumption patterns, showing with the proportion of the number of junior college in the total population (X1,%) .

Advanced industry, in recent years, the proportion of the third industry gradually increased, while the secondary industry remains the main position, besides, high-tech industries are booming. The regional industrial model is different, thus, the impact on carbon emissions is different. This index shows with the proportion of high tech industry output value in manufacturing value added (X2,%) .

Industrial rationalization, the proportion of three major industries determining the rationality of a regional industrial structure, shows with the proportion of the third industry added value in GDP (X3,%).

Energy structure, the three urban agglomerations are not resource-rich areas, but have their own unique geographical advantages. In recent years, the state vigorously develops non thermal power generation methods such as hydropower generation, so expressing in the ratio of non-thermal power generation accounted for the proportion of total power generation (X4,%).

Regional openness, which will accelerate economic growth, but can also cause a lot of problems, such as pollution and excessive consumption of resources, having a significant impact on carbon emissions. As the statistical yearbook does not give the total amount of social investment, so the index represents with the total foreign investment in total investment in social fixed assets (X5,%).

Innovation, which promotes economic development and is a key indicator to measure the regional economic development, shows with the proportion of the number of patent applications in per capita GDP ratio (X6, item / yuan / person) .

IV. Results and Discussion

4.1 Regional Economic Growth and Carbon Emissions

In Yangtze River Delta region, the development of industry lead to the rapid economic growth; In the Pearl River Delta region, economic growing mainly for clothing, toys, home appliances and other labor-intensive industries; Jing-Jin-Ji is a heavy chemical and capital-intensive region. As is shown in the figure 1 and Figure 2, the economy of Jiangsu and Guangdong develop very fast, while ranking second and third of carbon emission. The trend of economic growth and carbon emissions almost consistent, while carbon emissions began to decline after 2011. Hebei, Shanghai, Beijing, Tianjin, maintain a slow pace of economic development, and the growth trends are almost the same. Carbon emission of Hebei is the first consistently, meanwhile the growth rate is much faster. Shanghai, Tianjin, Beijing maintain a steady state of carbon emissions, and in recent years, there are a slight decline.

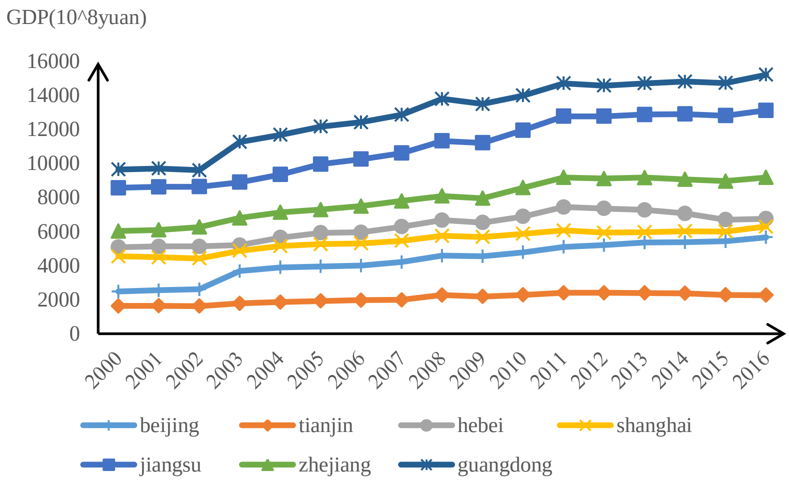

Fig. 1. GDP of seven provinces/cities(2000-2016)

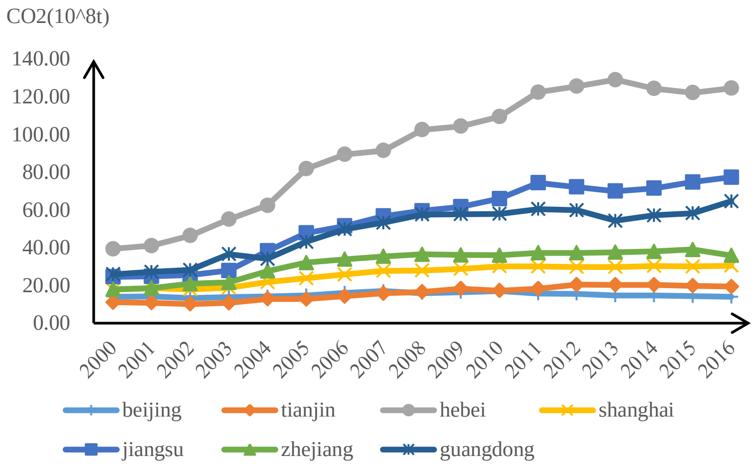

Fig. 2. Carbon emission of seven provinces/cities(2000-2016)

4.2 Decoupling Analysis

The period from 2000 to 2016 is divided into three stages of analysis, 2000-2005, 2006-2010 and 2011-2016. As is shown in Table 2, you can see the three stages of the decoupling state. In addition to Hebei, Jiangsu, Zhejiang provinces that three provinces are in the growth connection state in the first stage, others' states are all weak decoupling. The decoupling trend is not obvious no matter from the view of carbon emission or per capita carbon emission indicators. However there is a decoupling trend from the point of carbon emission intensity but there is still a certain distance from the strong decoupling. Data show that the growth rate remains relatively consistent between economic growth and carbon emissions. Due to the special political status, the development of Beijing mainly for tertiary industry, by 2016, the proportion of the tertiary industry reached 80.23%, so the trend of decoupling is most obvious among seven provinces/cities. Although Shanghai is the economic center in China, the

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proportion of the secondary industry is still 29.8% by the end of 2016, so the degree of decoupling is far away from Beijing. Tianjin, Jiangsu, Zhejiang, Guangdong, whose proportion of secondary and tertiary industries are almost the same and the decoupling index close to the critical value of 0.8. Hebei is the only region where the secondary industry dominates. The decoupling index of Hebei is even over one in the first stage, thus, different industrial structures have a significant effect on the provincial decoupling effect.

TABLE 2. The state of decoupling in seven provinces/cities（2000-2016）

	Year	%CO2/%GDP	State	%PCO2/%GDP	State	%GCO2/%GDP	State
Beijing	2000-2005	0.45	Weak decoupling	0.42	Weak decoupling	0.21	Weak decoupling
	2006-2010	0.57	Weak decoupling	0.47	Weak decoupling	0.32	Weak decoupling
	2011-2016	0.50	Weak decoupling	0.45	Weak decoupling	0.32	Weak decoupling
Tianjin	2000-2005	0.68	Weak decoupling	0.67	Weak decoupling	0.42	Weak decoupling
	2006-2010	0.69	Weak decoupling	0.59	Weak decoupling	0.35	Weak decoupling
	2011-2016	0.65	Weak decoupling	0.56	Weak decoupling	0.36	Weak decoupling
Hebei	2000-2005	1.03	Growth connection	1.02	Growth connection	0.70	Weak decoupling
	2006-2010	0.72	Weak decoupling	0.70	Weak decoupling	0.41	Weak decoupling
	2011-2016	0.75	Weak decoupling	0.73	Weak decoupling	0.49	Weak decoupling
Jiangsu	2000-2005	0.98	Growth connection	0.97	Growth connection	0.64	Weak decoupling
	2006-2010	0.67	Weak decoupling	0.65	Weak decoupling	0.35	Weak decoupling
	2011-2016	0.64	Weak decoupling	0.63	Weak decoupling	0.39	Weak decoupling
Zhejiang	2000-2005	0.92	Growth connection	0.87	Growth connection	0.55	Weak decoupling
	2006-2010	0.60	Weak decoupling	0.57	Weak decoupling	0.34	Weak decoupling
	2011-2016	0.69	Weak decoupling	0.69	Weak decoupling	0.46	Weak decoupling
Shanghai	2000-2005	0.73	Weak decoupling	0.67	Weak decoupling	0.47	Weak decoupling
	2006-2010	0.69	Weak decoupling	0.59	Weak decoupling	0.41	Weak decoupling
	2011-2016	0.70	Weak decoupling	0.66	Weak decoupling	0.49	Weak decoupling
Guangdong	2000-2005	0.73	Weak decoupling	0.70	Weak decoupling	0.43	Weak decoupling
	2006-2010	0.75	Weak decoupling	0.68	Weak decoupling	0.41	Weak decoupling
	2011-2016	0.65	Weak decoupling	0.63	Weak decoupling	0.42	Weak decoupling

TABLE 3. Panel data unit root test results

		LLC	Breitung	IPS	ADF-Fisher Chi-square	PP-Fisher Chi-square	conclusion
lntc	Statistic	-4.65718	-0.05174	3.15496	4.48608	4.0226	Non-stationary
	Prob.	0.0000	0.4794	0.9992	0.9918	0.9953	
1nd difference	Statistic	-9.26429	-3.46373	-5.00479	46.7664	59.3117	Stationary
	Prob.	0.0000	0.0003	0.0000	0.0000	0.0000	
lny	Statistic	0.50876	-0.17972	0.90225	7.78748	8.57557	Non-stationary
	Prob.	0.6945	0.4287	0.8165	0.9001	0.8572	
1nd difference	Statistic	-8.75097	-0.8375	-5.22827	48.6209	84.1852	Stationary
	Prob.	0.0000	0.2012	0.0000	0.0000	0.0000	
lny^2	Statistic	-1.25589	-0.70018	-0.71845	16.6765	15.9285	Non-stationary
	Prob.	0.1046	0.2419	0.2362	0.2738	0.3178	
1nd difference	Statistic	-8.58538	-0.8948	-5.00018	46.9553	76.6064	Stationary
	Prob.	0.0000	0.1854	0.0000	0.0000	0.0000	

4.3 Panel Date Analysis

In order to avoid spurious regression, stationarity test of panel data is analyzed firstly. Levin-Lin-Chiu test (LLC test), Breitung test, Im, Pesaran and Shin W-stat test (IPS test), ADF-Fisher Chi-square test and PP-Fisher Chi-square test are adopted to test the stationarity of the total carbon emissions series and GDP series. The results of the test are shown in Table 3. At the level of 5%, the first difference of lny and $\ln y^2$ is not significant under Breitung test, and the others' first differences are significant.

Through the above analysis, we can see lntc, lny and $\ln y^2$ series are integrated of order one, indicating that co-integration test can be used. In this paper, we selected the Johansen test for panel data co-integration test. The results show that the two series are co-integrated, so we can conclude that there is a long-term equilibrium relationship between them. The Hausman test is performed on the sample data, suggesting that the chaperonage probability is approximately zero and the null hypothesis is rejected at the level of 5%, and fixed effect model should be selected. There is a long-term equilibrium relationship between the economic growth and carbon emissions in Yangtze River Delta, the Pearl River Delta and Beijing-Tianjin-Hebei provinces. The conintegration equation of variables is given as follows(equation 3).

$$\ln tc = 3.815638 + 0.410696 \ln y \quad (3)$$

It can be seen from the cointegration equation that there is a long-term equilibrium relationship between carbon emissions and per capita GDP. There is a positive correlation between GDP, Whenever the per capita GDP increases by 1%, the carbon emissions increased by 0.41%, indicating that with economic growth, the carbon emissions of the Yangtze River Delta, Pearl River Delta and Beijing-Tianjin-Hebei Seven provinces will increase. And according to the economic growth and changes in carbon emissions, seven provinces and cities are in a weak decoupling state, consistent with the previous decoupling analysis results.

4.4 Regression Analysis

In order to eliminate the common influence of policies and technologies on the carbon emissions in each province, the time trend variable lnt is introduced to the formula. Table 4 shows the regression results of the logarithm for carbon emissions and carbon intensity. According to the empirical results of panel data, this paper chooses the fixed effect model to estimate the formula 3.

TABLE 4. The regression results of the dependent variables are the logarithm (lnC) of the total carbon emissions and the logarithm (lnci) of the carbon emission intensity

Variables	lnC Model 1	Model 2	Model 3	lnci Model 1	Model 2	Model 3
LNY	5.716214*** (10.2595)	2.63269*** (3.401284)	2.177056*** (2.458274)	6.983593*** (11.4496)	3.442046*** (4.668017)	3.22782*** (3.756754)
LNY2	-0.256354*** (-9.7583)	-0.1006*** (-2.62979)	-0.08293** (-1.94075)	-0.369495*** (-12.8479)	-0.19403*** (-5.32423)	-0.181728*** (-4.383698)
X1		-1.98031*** (-2.87027)	-2.15018*** (-2.99854)		-2.21548*** (-3.37078)	-2.155854*** (-3.098818)
X2		0.281654*** (3.183766)	0.269983*** (2.684859)		0.272361*** (3.231787)	0.320439*** (3.284523)
X3		-1.02015*** (-2.44856)	-0.87595** (-1.93346)		-1.329259*** (-3.3491)	-1.26852*** (-2.88601)
X4		0.855467** (1.831215)	0.702059* (1.441933)		0.946805*** (2.127499)	0.751685* (1.591293)
X5		0.055359 (0.408498)	-0.07952 (-0.52187)		0.134338 (1.040576)	0.035631 (0.241028)
X6		-0.00031 (-0.01965)	0.000542 (0.029792)		0.038666*** (2.586181)	0.029274* (1.658951)
LNT	-0.018695 (-0.4592)	0.006168 (0.144903)	0.090718 (0.935472)	-0.091534*** (-2.0539)	-0.3728 (-0.91918)	-0.07357 (-0.78198)
coefficient	-23.49101*** (-8.0002)	-7.9273** (-1.98589)	-5.26285 (-1.12594)	-33.67542*** (-10.4762)	-15.4603*** (-4.06556)	-14.5072*** (-3.19904)
F	437.8116	363.0048	356.1548	347.3471	382.976	312.6667
R^2	0.9765	0.9839	0.9849	0.9705	0.9846	0.9847

Note: The values in parentheses indicate the t values of the regression; *** indicates the 5% level; ** indicates the 10% level; * indicates the 20% level.

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From the results of model 1, it can be seen that the coefficients of per capita GDP and its' quadratic term are significant at the level of 5%, and the coefficient of the per capita GDP is negative. Based on the outcome, Per capita GDP and carbon emissions, carbon intensity are inverted U-shaped, in line with environmental Kuznets hypothesis. In order to test the robustness of Model 1, this paper adds six control variables to the formula ,education level, advanced industry, industry rationalization, regional openness, energy structure and innovation ability. The regression analysis results shows that the coefficients of per capita GDP and its' quadratic term are significant at the level of 5%, and the coefficient of the per capita GDP is negative. Thus the environmental Kuznets curve hypothesis is still true. In order to solve the endogenous problem of model 2, this paper adopts the lagging instrument variables.

Compared with model 2 and model 3, the two models did not change at the 5% level significantly, but the value of R^2 in model 3 was larger than that of model 2, which indicates that the overall regression effect of model 3 is more significant. Compared with model 2, the two variables of regional openness and innovation ability are not significant in model 3, and the sign of these two variables are changed. After using the tool variable, the variable X5 changed from 0.134338 to 0.035631, which was nearly four times higher, due to the existence of endogeneity of lny and lny^2, resulting in a high estimation of variable X5. It is shown that there is a strong correlation between the endogenous variables in the lag and the current value, so the selection of tool variable is suitable for the model.

According to the regression results of model 3, the per capita GDP per is positive and its' quadratic term is negative, All the variables are significant at the level of 5% except the quadratic term of GDP per capita which is significant at the level of 10%.Model 3 conforms to the inverted U-shaped curve in the EKC hypothesis. Regional openness and innovation capacity variables are not obvious, indicating that the foreign investment and innovation of seven provinces/cities have little effect on the regional carbon emission.

The high-tech industry has a significant positive effect on the regional carbon emissions, and its proportion of the output value in the added value of the manufacturing industry increases by 1%,the carbon emission and carbon intensity will increase by 0.27% and 0.32% respectively. The energy structure is significant at the level of 20%, but it has grand impact on regional carbon emissions. The proportion of non-coal power increases 1%, then the total carbon emissions and carbon intensity increases by 0.70% and 0.75% respectively. Education level and industrial rationalization have a significant negative effect. The total carbon emissions and carbon intensity will reduce by 2.15% and 2.16% respectively when the level of education increases 1%. The total carbon emissions and carbon intensity will decrease by 0.87% and 1.27% respectively when the proportion of the tertiary industry increases by 1%.

(5) Regional carbon emission peak forecast

Select the model 3 and remove the variables that are not significant, the equation of the total carbon emission and carbon intensity are as follows:

$$\begin{aligned}\ln C_{it} &= 2.177056(\ln y) - 0.08293(\ln y)^2 - 2.15018X_1 \\ &+ 0.269983X_2 - 0.87595X_3 + 0.702059X_4 \\ &+ 0.090718\text{lnt} - 5.26285\end{aligned} \quad (4)$$

$$\begin{aligned}\ln ci_{it} &= 3.22782(\ln y) - 0.181728(\ln y)^2 - 2.155854X_1 \\ &+ 0.320439X_2 - 1.26852X_3 + 0.751685X_4 \\ &+ 0.029274X_6 - 0.07357\text{lnt} - 14.5072\end{aligned} \quad (5)$$

The peak of the equations (4) and (5) are calculated without considering the control variable X_i. The peak of the carbon emission is predicted to be 8308.3954 million tons and the corresponding peak of per capita GDP (2000 is the base period) is 501753.9756 yuan; The peak of carbon emission intensity is predicted to be 0.8401 ton/million and the corresponding peak of per capita GDP is 7193.3331 yuan. According to the peak of carbon intensity, we can see that the seven provinces/cities have all reached the peak of carbon intensity, and the intensity of carbon emissions in these urban agglomerations was lower than 0.8401 ton/Million yuan in 2008. But according to the peak of carbon emissions, it can be seen that the peak of total carbon emission has not reached.

V. Conclusions and Suggestions

In this paper, the economic growth and carbon emissions of the seven provinces/cities in China's developed urban agglomerations are measured by Tapio elasticity coefficient method and lagging instrument variables of panel data and

EKC curve. The conclusions are as follows:

According to the three decoupling index, the provinces corresponding to the developed urban agglomerations have realized weak decoupling, but the gaps between the provinces are large, especially the gap between Jing-Jin-Ji. Different developing patterns and resource agglomerative form lead to the diverse decoupling state between different provinces in the same region. From the aspect of decoupling state, Beijing ranks first in seven provinces/cities, and Hebei is the last. Therefore, we should strengthen the regional integration of resources, coordinate and promote regional integration, take advantage of regional resources and elements form cross-regional cooperation.

Industrial structure has offset effect on carbon emissions, meanwhile, energy structure has a positive effect and the education level has a negative effect on carbon emission. Advanced industry promotes carbon emission, which reflects the characteristics of energy-saving emission reduction of advanced industry is not obvious,however, industrial rationalization curbs the growth of carbon emissions, so the impact of industrial structure optimization for carbon emissions depends on the impact of the size of the two. Compared with the historical data, we can see that the energy structure continues optimizing, indicating that current energy structure diversity has not curbed the increase of carbon emission. Energy structure should be further optimized, non-coal energy should be vigorously developed and the proportion of coal power generation should be reduced. The degree of education suppresses the growth of carbon emissions and has the biggest impact among these variables, indicating that the higher the level of education the more attention can be paid to the environment. Because of this, we should try our best to increase investment in education to raise awareness of saving energy and reducing energy.

Hebei Province is the focus of controlling carbon emissions in seven provinces/cities, which is the first to break through the provincial average peak carbon emissions and its amount of carbon emission has been increased for many years. According to the regression analysis of panel data, it can be seen that there existing EKC curves of total carbon emission and carbon intensity in developed urban agglomeration. Based on the estimation of the EKC curve peak, although the developed urban agglomerations have all reached the peak of carbon intensity before 2014, have not reaching the peak of total carbon emissions. Hebei has the most rapid growth of carbon emissions because of the high proportion of steel industry in GDP which results in a large total of coal consumption. Therefore, Hebei need to limit the excessive development of the steel industry and restrict the development of high energy consumption and heavy pollution iron and steel enterprises to promote the economy and take the road of sustainable development.

The impact of regional openness and technological innovation on carbon emissions did not meet expectations, indicating the introduction of foreign investment and patent inventions do not have characteristics of saving energy and reducing emissions. The results show that the influence coefficients of regional openness and technological innovation are not significant, and the signs of them changes in different models.

The introduction of foreign capital and technological innovation do not have a substantial impact on carbon emissions, distinguishing from previous conclusion. It is proposed to increase the introduction of foreign capital and inventions of energy-saving emission reduction and give priority of these foreign investment and patents with characteristics of energy-saving and emission-reducing.

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