Research on Decoupling and Influencing Factors of Carbon Emissions in the Construction Industry of Coastal Provinces

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Abstract. On the basis of the panel data of 11 provinces in 2005~2021, this paper chooses the construction industry of China's coastal provinces as the research object, studying the decoupling relationship and degree of the construction industry's economic growth and carbon emissions with Tapio decoupling model. The results show that the relationship between the economic growth and carbon emissions of these areas varies as "weak decoupling-expansive coupling-weak decoupling-strong decoupling", and the decoupling status of different coastal provinces is obviously different. Based on the analysis above, this paper utilizes the LMDI decomposition method to decompose the decoupling elasticity, concludes that the energy intensity effect is the main factor hindering the decoupling of economic growth and carbon emissions in the construction industry. Then, some suggestions are put forward, such as optimizing the energy consumption structure, improving energy efficiency, and establishing a building carbon emission trading mechanism.

Keywords: construction industry; economic growth; carbon emissions; decoupling mode

1 Introduction

With the acceleration of urbanization construction and rapid economic growth in China, the contradiction between resources, environment, and economy is becoming increasingly prominent. As a pillar industry of the national economy, the construction industry has a significant radiation and shaking effect on other industrial sectors. At the same time, it is also a high energy consumption industry. The annual consumption, when converted into standard coal, shows an increasing trend year by year, which inevitably leads to an increase in carbon emissions and has an undeniable negative impact on the environment[1]. Improving energy utilization efficiency, developing low-carbon products and services, and ensuring economic growth while reducing carbon emissions have become the development trend of China's low-carbon economy[2]. Analyzing the decoupling relationship between the economic development of the construction industry and carbon emissions in coastal provinces can provide a basis for evaluating their low-

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carbon development level. Therefore, this article takes the construction industry in coastal provinces of China as the research object, and quantitatively analyzes the decoupling characteristics and changes between economic growth and carbon emissions in the construction industry through the Tapio decoupling model. The LMDI decomposition method is used to deeply study the relevant factors affecting decoupling elasticity and provide targeted suggestions.

2 Related Theories and Models

2.1 Decoupling Model

According to the Environmental Kuznets Curve (EKC) hypothesis, economic growth consumes more resources and puts greater pressure on the environment. When effective measures are taken, lower resource consumption and environmental pressure also accelerate economic growth, a process known as decoupling[3]. Tapio used decoupling elasticity and constructed decoupling indicators when studying the relationship between economic growth and carbon emissions in the transportation sector. The definition of decoupling is a state where the elasticity value between traffic volume and economic growth is less than 1. The ratio of the degree of change in carbon emissions caused by changes in economic development reflects the sensitivity of carbon emissions to economic changes[4].

$$r = \frac{\Delta VOL/VOL}{\Delta GDP/GDP} \tag{1}$$

In equation (1), r represents the elastic value of transportation volume; VOL represents the transportation volume,ΔVOL represents the change in transportation volume;ΔGDP is the amount of change in GDP.

The Tapio decoupling model divides decoupling states into: expansionary negative decoupling, strong negative decoupling, weak negative decoupling, weak decoupling, strong decoupling, decaying decoupling, expansionary coupling, and decaying coupling, as shown in Table 1.

Table 1. Tapio decoupling state and decoupling elasticity

Decoupling state	$\Delta C/C$	$\Delta G/G$	Decoupling elasticity coefficient x	significance
Dilatant negative decoupling	>0	>0	x >1.2	Economic growth, accompanied by a sharp increase in carbon emissions
Strong negative decoupling	>0	<0	x <0	During economic recession, carbon emissions increase
Weak negative decoupling	<0	<0	0<x <0.8	The rate of carbon emission reduction is lower than the rate of economic recession
Weak decoupling	>0	>0	0<x <0.8	The growth rate of carbon emissions is slower than economic growth

Strong decoupling	<0	>0	x <0	Economic growth while reducing carbon emissions
Decline decoupling	<0	<0	x >1.2	The economic downturn is slower than the reduction of carbon emissions
Expansive coupling	>0	>0	0.8<x <1.2	The increase in carbon emissions is comparable to the speed of economic growth
Decay coupling	<0	<0	0.8<x <1.2	The speed of economic downturn and carbon emission reduction is comparable

This article is based on the Tapio model and selects the carbon emissions and GDP of the construction industry in 11 coastal provinces from 2005 to 2021 as the main indicators to measure the economic growth and carbon emissions of the construction industry in coastal provinces. The model is constructed as follows:

$$x = \frac{\Delta C/C}{\Delta G/G} \tag{2}$$

In equation (2), x represents the elasticity coefficient of decoupling between economic growth and carbon emissions in the construction industry, C represents the carbon emissions in the construction industry, and ΔC represents the change relative to the base period's carbon emissions; G represents the gross domestic product of the construction industry, and ΔG represents the change relative to the base period's gross domestic product of the construction industry.

2.2 LMDI Decomposition Method

At present, there are two main types of factor decomposition methods. One is the Structural Decomposition Method (SDA) based on input-output tables as data support, and the other is the Exponential Decomposition Method (IDA) that only requires output sum data and is suitable for time series analysis. This article selects the LMDI decomposition method from IDA.

$$C = \sum_t \frac{C_t}{E_t} \times \frac{E_t}{E} \times \frac{E}{G} \times G = \sum_t F_t \times M_t \times T \times G \tag{3}$$

Among them, C is the carbon emissions of the construction industry, Ct is the carbon emissions of the t-th energy source, Et is the consumption of the t-th energy source, E is the primary energy consumption, and G is the gross domestic product of the construction industry[5]. Ft represents the emission intensity of different types of energy, that is, the carbon emissions per unit of consumption of the t-th type of energy, Mt represents the proportion of the t-th type of energy in one-time energy consumption, and T represents the energy consumption per unit of GDP in the construction industry, that is, the energy intensity of the construction industry.

According to equation (3), the factors affecting carbon emissions in the construction industry include four aspects: carbon emission intensity effect, energy structure effect, energy intensity effect, and industrial scale effect. Let $\triangle C_{kok} = C^k - C^o$,$\triangle C_{kok}$is the change in total carbon emissions,C^o、$C^k$are the base period carbon emissions and the$k$period carbon emissions, that is

$$\triangle C_{kok} = C^k - C^o = \triangle C_F + \triangle C_M + \triangle C_T + \triangle C_G \quad (4)$$

Among them,$\triangle C_F$、$\triangle C_M$、$\triangle C_T$、$\triangle C_G$ separate carbon emission scale effects.$\Delta C_F = \sum_t \frac{C_t^k - C_t^o}{In(C_t^k/C_t^o)} \times In(F_t^k/F_t^o)$ is the carbon emission intensity effect, Ft represents the emission intensity of various types of energy, that is, the carbon emissions of the t-th type of energy consumed per unit.Due to the fixed carbon emissions of the t-th type of energy per unit[5],so $F_t^0 = F_t^k$,that is

$$\Delta C_F = 0; \quad (5)$$

$$\Delta C_M = \sum_t \frac{C_t^k - C_t^o}{In(C_t^k/C_t^o)} \times In(M_t^k/M_t^o) \text{is the energy structure effect;} \quad (6)$$

$$\Delta C_T = \sum_t \frac{C_t^k - C_t^o}{In(C_t^k/C_t^o)} \times In(T_t^k/T_t^o) \text{is the energy intensity effect;} \quad (7)$$

$$\Delta C_G = \sum_t \frac{C_t^k - C_t^o}{In(C_t^k/C_t^o)} \times In(G^k/G^o) \text{is the economic scale effect.} \quad (8)$$

Substituting formulas (5) (6) (7) and (8) into (2) yields, get $x = \frac{\Delta C/C}{\Delta G/G} = \frac{(\Delta C_F + \Delta C_M + \Delta C_T + \Delta C_G)/C}{\Delta G/G} = \frac{\Delta C_F/C}{\Delta G/G} + \frac{\Delta C_M/C}{\Delta G/G} + \frac{\Delta C_T/C}{\Delta G/G} + \frac{\Delta C_G/C}{\Delta G/G} = x_F + x_M + x_T + x_G$ Among them, $x_F$is the decoupling elasticity of carbon emission intensity, $x_M$is the decoupling elasticity of energy structure, $x_T$is the decoupling elasticity of energy intensity, and $x_G$is the decoupling elasticity of economic growth.

3 Empirical Analysis

3.1 Data Sources and Processing

This article selects indicators such as the gross domestic product, total energy consumption, and energy intensity of the construction industry in coastal provinces. The GDP data of the construction industry is sourced from CHINA STATISTICAL YEARBOOK on CONSTRUCTION while the consumption data of raw coal, coke, crude oil, kerosene, diesel, gasoline, fuel oil, natural gas, and electricity are sourced from China Energy Statistical Yearbook.

3.2 Decoupling Analysis of Economic Growth and Carbon Emission in Construction Industry

According to the actual carbon emissions of the construction industry, the consumption of raw coal, coke, crude oil, kerosene, diesel, gasoline, fuel oil, natural gas and electricity (75% of the electricity consumption is derived from raw coal combustion, the rest is wind power, nuclear power, etc.) is converted into standard coal consumption and carbon emission coefficient of standard coal is multiplied to obtain carbon emissions[6]. In this paper, the carbon emissions of the construction industry can be expressed as: $TC = \sum_t E_t \times \eta_t \times \lambda$

In the formula, TC represents the total carbon emissions, Et represents the consumption of the t-th energy source, ηt is the reference coefficient for converting the energy in t to standard coal[7] (see Table 2), λ is the carbon emission coefficient for standard coal.

Table 2. Conversion coefficient of actual standard coal for each energy source

energy	**raw coal**	**coke**	**crude oil**	**kero-sene**	**diesel**
Conversion coeffi-cient	0.7143	0.9714	1.4286	1.4714	1.4571
energy	**Gaso-line**	**fuel oil**	**natural gas**	**electric-ity**	
Conversion coeffi-cient	1.4714	1.4286	1.3300	1.2290	

Note: Unit of conversion coefficient for standard coal, natural gas—tec/10^4m^3、electricity—tec/10^4kw.h、Other energy —tec/t

Table 3. Decoupling Status of Construction Industry in Coastal Provinces from 2005 to 2021

year	$\Delta C/C$	$\Delta G/G$	x	Decoupling state
2005	0.044	0.171	0.257	Weak decoupling
2006	0.105	0.167	0.629	Weak decoupling
2007	0.097	0.178	0.545	Weak decoupling
2008	-0.076	0.162	-0.470	Strong decoupling
2009	0.090	0.171	0.529	Weak decoupling
2010	0.006	0.195	0.502	Weak decoupling
2011	0.172	0.182	0.482	Expansive coupling
2012	-0.047	0.145	-0.323	Strong decoupling
2013	0.055	0.135	0.410	Weak decoupling
2014	-0.011	0.092	-0.121	Strong decoupling
2015	-0.003	0.011	-0.263	Strong decoupling
2016	0.026	0.044	0.601	Weak decoupling
2017	0.006	0.084	0.070	Weak decoupling
2018	-0.076	0.084	-0.903	Strong decoupling
2019	0.018	0.014	1.327	Dilatant negative decoupling
2020	-0.002	0.058	-0.042	Strong decoupling
2021	-0.027	0.096	-0.283	Strong decoupling

According to Table 3 and Figure 1, it can be seen that during the 17 years from 2005 to 2021, the carbon emissions from the construction industry in coastal provinces of China fluctuated greatly, with the lowest growth rate being -0.076 and the highest reaching 0.172. In 2011, there was a significant increase, and after 2012, there was a W-shaped fluctuation, reaching the lowest value in 2018. Since then, the trend of carbon emissions growth has been hovering at a low level. During the same period, the overall growth of the total output value of the construction industry was relatively stable. Except for the low growth rates in 2015 and 2019, it remained at the level of 0.140-0.190 from 2005 to 2013, and 0.050-0.090 from 2014 to 2021. Moreover, the growth rate of the total output value slowed down significantly after 2015.

Combining the growth comparison of the two, the economic growth rate of the construction industry is higher than the growth rate of carbon emissions, and both have a slowing trend. Therefore, from 2005 to 2007 and from 2009 to 2010, carbon emissions in the construction industry were weakly decoupled from economic growth. Although carbon emissions increased with economic development, the degree of environmental damage was lower than that of economic growth. In 2011, the decoupling state of the construction industry showed an expansionary coupling, with carbon emissions comparable to the economic growth rate of the construction industry. The decoupling elasticity coefficient gradually decreased between 2012 and 2015, and between 2016 and 2018, achieving a transition from weak decoupling to strong decoupling. In 2019, carbon emissions increased sharply, and the decoupling coefficient reached its highest value. Since then, it has been decreasing year by year, and the decoupling trend is obvious.

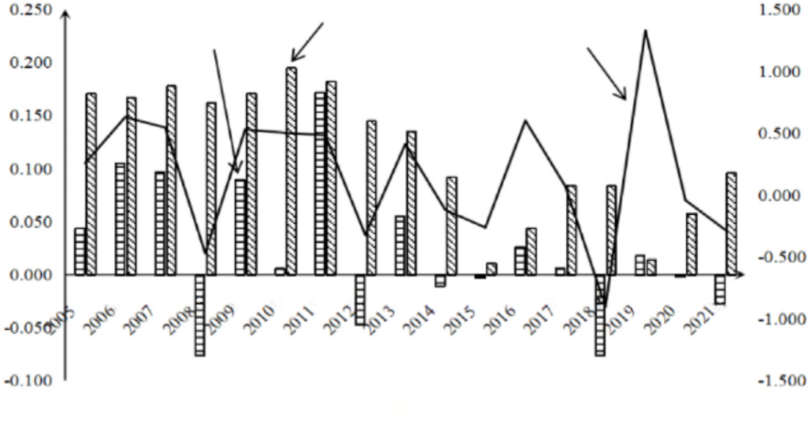

Fig. 1. Carbon emissions and total output value growth rate of the construction industry in coastal provinces from 2005 to 2021, as well as decoupling status

In order to better illustrate the decoupling status between economic growth and carbon emissions in the construction industry of coastal provinces, this article calculates the decoupling elasticity coefficient for each province according to formula (2), as shown in Table 4. According to the value of the decoupling elasticity coefficient, the decoupling status of each province can be determined, as shown in Table 5.

Table 4. Annual decoupling elasticity coefficient values in coastal provinces

province	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
liao-ning	0.635	0.205	1.017	0.261	0.47	0.46	0.27	-1.26	0.050	4.516	0.819	0.374	0.472	28.23	15.01	1.373	0.624
tian-jin	2.061	0.741	0.918	6.962	-0.23	0.940	0.709	0.643	0.143	0.299	0.842	1.040	0.275	0.959	0.069	0.109	0.099
shan-dong	0.978	-0.153	0.043	0.043	1.003	0.488	0.629	-1.50	0.267	0.467	-3.56	0.399	0.030	-1.25	0.950	-2.49	1.050
hebei	1.042	0.481	0.059	0.407	0.324	0.724	0.619	0.153	-1.59	-0.86	-5.40	0.975	-2.23	-2.85	-8.90	18.70	-3.56
jiangsu	0.229	0.513	0.194	-0.05	0.973	0.634	0.611	-0.31	0.795	0.520	-8.91	-0.12	-2.70	0.380	0.283	-0.43	0.796
Shanshan	-0.21	-0.265	-0.239	0.179	0.401	-0.90	2.033	-0.19	-2.19	-1.41	0.673	0.256	0.776	-0.21	0.456	1.169	0.320
zhejiang	0.788	0.552	0.586	0.568	0.681	0.783	0.235	-0.01	0.769	0.193	0.581	-0.50	0.358	-0.47	0.048	-5.88	0.274
fu-jian	1.017	0.818	-0.108	7.207	0.346	0.305	0.374	-1.45	1.776	0.106	0.082	0.323	0.505	0.378	0.206	-1.56	0.109
Guangdong	2.599	0.511	0.892	-0.16	0.743	0.397	0.282	0.268	0.123	0.599	-2.42	1.466	0.248	0.101	-0.44	0.489	0.137
guangxi	1.242	2.685	-0.112	-1.83	0.349	-4.86	0.601	0.530	-2.97	0.927	2.992	-2.05	0.520	5.743	3.077	3.652	0.527
hai-nan	0.476	0.433	0.503	-0.74	1.101	0.746	0.675	0.831	14.29	-3.74	8.039	0.146	1.544	0.260	-0.59	0.722	0.610

Table 5. Decoupling Status of Construction Industry in Coastal Provinces from 2005 to 2021

province	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
liaoning	Weak decoupling	Weak decoupling	Expansive coupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Decline decoupling	Decay coupling	Weak negative decoupling	Weak negative decoupling	Decline decoupling	Dilatant negative decoupling	Dilatant negative decoupling	Weak decoupling
tianjin	Dilatant negative	Weak decoupling	Expansive coupling	Dilatant negative	Strong decoupling	Expansive coupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Expansive coupling	Expansive coupling	Weak negative deco	Decay coupling	Weak decoupling	Weak decoupling	Weak decoupling

	decoupling			decoupling									coupling				
shandong	Expansive coupling	Strong decoupling	Weak decoupling	Weak decoupling	Expansive coupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Expansive coupling	Strong decoupling	Expansive coupling
hebei	Dilatant negative decoupling	Expansive coupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Strong decoupling	Strong negative decoupling	Expansive coupling	Strong decoupling	Strong decoupling	Strong decoupling	Dilatant negative decoupling	Strong decoupling
jiangsu	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Expansive coupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Strong decoupling	Strong decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling
shanghai	Strong decoupling	Strong decoupling	Strong decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Dilatant negative decoupling	Strong decoupling	Strong decoupling	Strong decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Expansive coupling	Weak decoupling
zhejiang	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Strong decoupling	Weak negative decoupling	Strong decoupling	Weak decoupling
fujian	Expansive coupling	Weak decoupling	Strong decoupling	Dilatant negative decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Dilatant negative decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling
guangdong	Dilatant negative deco	Weak decoupling	Expansive coupling	Strong decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Dilatant negative deco	Weak decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Weak decoupling

	upling											upling					
guangxi	Dilatant negative decoupling	Dilatant negative decoupling	Strong decoupling	Strong decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Expansive coupling	Dilatant negative decoupling	Strong decoupling	Weak decoupling	Dilatant negative decoupling	Dilatant negative decoupling	Dilatant negative decoupling	Weak decoupling
hainan	Weak decoupling	Weak decoupling	Weak decoupling	Strong decoupling	Expansive coupling	Weak decoupling	Weak decoupling	Expansive coupling	Dilatant negative decoupling	Strong negative decoupling	Dilatant negative decoupling	Weak decoupling	Dilatant negative decoupling	Weak decoupling	Strong decoupling	Weak decoupling	Weak decoupling

From Tables 4 and 5, it can be seen that there are significant differences in the overall decoupling status among coastal provinces, with a significant difference in the average decoupling coefficient. This is because the actual situation of economic growth and carbon emissions in the construction industry in each province is different. From the perspective of the average decoupling elasticity, Liaoning Province has the highest value, reaching 3.149. Between 2014 and 2020, there were two expansionary negative decoupling and two recessive decoupling, which are closely related to the coal based energy structure that Liaoning has formed for a long time and its rapid economic development in recent years. Affected by the international financial crisis in 2009, the development speed of China's construction industry has slowed down, and some provinces have experienced expansionary coupling. The average decoupling coefficient in Jiangsu is the lowest, at -0.389. Except for 2009, which was an expansionary coupling, all other years have maintained strong and weak decoupling states.

Further analysis of the decoupling status of coastal provinces shows that the economic growth and carbon emissions of the construction industry in Shanghai, Jiangsu, and Zhejiang have been in a decoupling state since 2005, reflecting the significant effects of low-carbon, energy-saving, and environmental protection measures taken by the three provinces in the construction industry. While maintaining sustained and stable growth, the carbon emissions of the construction industry have all decreased, in order to achieve a win-win goal of economic growth and carbon emissions. The highest decoupling elasticity coefficient in Fujian is 7.207, the highest in Guangdong is 2.599, and the highest in Guangxi is 2.992. The economic growth of the construction industry comes at the cost of sacrificing the environment, and the carbon emissions in the construction industry are relatively serious. Shandong and Hebei have been in a weak decoupling state for most years, but show a cyclical change of "weak decoupling expansion coupling weak decoupling". This indicates that the carbon emissions of the construction industry in the three provinces have a sharp increase trend in the short term, and the decoupling level still needs to be improved. During the calculation period in

Tianjin and Hainan, there were multiple expansionary negative decoupling and expansionary coupling, indicating that both provinces need to further strengthen their carbon emission control efforts in the construction industry.

3.3 Exploration of Factors Affecting Decoupling Elasticity Based on LMDI Decomposition Method

According to equations (3) to (8) , decompose the decoupling elasticity coefficient $x$of the construction industry in coastal provinces from 2005 to 2021. According to equation (5), it can be inferred thatΔCF =0, indicating that energy structure, energy intensity, and economic growth are the main factors affecting carbon emissions in the construction industry[8]. The decoupling elasticity is decomposed into energy structure decoupling elasticity xM, energy intensity decoupling elasticity xT, and economic growth decoupling elasticity xG using the LMDI decomposition method, as shown in Table 6.

Table 6. decoupling elasticity indicators of various influencing factors on carbon emissions in the construction industry

Year	Energy structure decoupling elasticity x_M	Energy intensity decoupling elasticity x_T	Economic growth decoupling elasticity x_G	Decoupling elasticity coefficient x	Decoupling state
2005	-0.034	0.184	0.107	0.257	Weak decoupling
2006	-0.027	0.708	-0.052	0.629	Weak decoupling
2007	-0.041	0.843	-0.257	0.545	Weak decoupling
2008	-0.027	-0.100	-0.343	-0.470	Strong decoupling
2009	-0.112	0.274	0.143	0.529	Weak decoupling
2010	0.109	0.278	0.115	0.502	Weak decoupling
2011	0.023	0.584	-0.125	0.482	Expansive coupling
2012	0.105	-0.431	0.231	-0.323	Strong decoupling
2013	0.121	0.491	-0.202	0.41	Weak decoupling
2014	0.059	-0.248	0.068	-0.121	Strong decoupling
2015	0.098	-0.129	-0.232	-0.263	Strong decoupling
2016	0.111	0.306	0.184	0.601	Weak decoupling
2017	-0.095	0.286	-0.121	0.07	Weak decoupling

2018	0.013	-1.134	0.218	-0.903	Strong decoupling
2019	0.134	0.867	0.326	1.327	Dilatant negative decoupling
2020	0.099	-0.219	0.078	-0.042	Strong decoupling
2021	0.101	-0.321	-0.063	-0.283	Strong decoupling

According to Table 6 and Figure 2, it can be seen that:

① Energy structure elasticity: Energy structure elasticity has the smallest contribution to the decoupling elasticity of the construction industry. Due to the fact that the construction industry is still dominated by traditional petrochemical fuels, the energy structure is relatively stable, with a maximum value of 0.134 and a minimum value of -0.112. Except for the negative impact on carbon emissions from 2005 to 2009 and 2017, it has a positive impact in the rest of the years. Among them, the impact effect was significant in 2019, and the contribution rate showed an upward trend. The energy structure has a tendency to constrain the economic growth of the construction industry and decouple carbon emissions, and further optimization of the energy structure is needed.

② Energy intensity elasticity: The energy intensity elasticity of the construction industry has always been in a state of drastic fluctuations in carbon emissions, and its elasticity is consistent with the trend of decoupling coefficient changes, indicating a high degree of correlation between the two. Energy intensity elasticity directly determines the change of decoupling coefficient. The extensive use of energy in China's construction industry has led to low energy efficiency, which directly affects carbon emissions. Therefore, the energy intensity effect is the main factor hindering the decoupling of economic growth and carbon emissions in coastal provinces.

③ Economic growth elasticity: Economic growth elasticity has experienced repeated small fluctuations. In 2019, there was a maximum turning point in energy intensity decoupling elasticity, energy structure decoupling elasticity, and decoupling coefficient. The main reason is that the country has increased investment in the construction field, and the expansion of the construction industry has led to higher carbon emissions. However, this situation has improved in 2021.

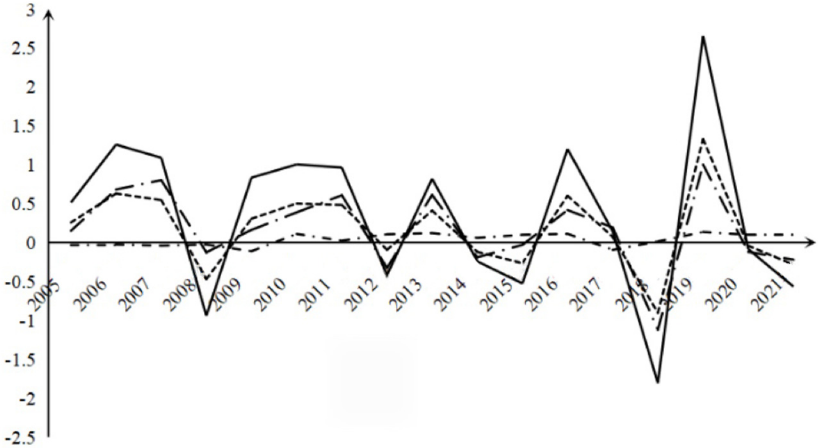

Fig. 2. Trend chart of decoupling elasticity indicators for various influencing factors of carbon emissions in the construction industry

4 Suggestions

With the rapid development of the construction industry economy in coastal provinces, carbon emissions are also showing an increasing trend. From decoupling analysis, it can be seen that the economic growth of the construction industry and carbon emissions from 2005 to 2021 showed a characteristic of "weak decoupling expansion coupling weak decoupling strong decoupling". After 2016, it began to transition from weak decoupling to strong decoupling; There are significant regional differences in decoupling status, with Jiangsu, Zhejiang, and Shanghai having the best decoupling effect. However, achieving complete decoupling is still a long way to go. By decomposing decoupling elasticity, it is concluded that the energy intensity effect is the main factor inhibiting economic growth and carbon emissions decoupling in the construction industry. Based on the current situation of decoupling economic growth and carbon emissions in the construction industry in coastal provinces, the following suggestions are proposed:

Optimizing Energy Consumption Structure. The energy structure of the construction industry is relatively stable, which has a positive effect on decoupling economic growth and carbon emissions. The carbon emission coefficient of coal is higher than that of other energy sources[9], so it is necessary to increase the proportion of new energy sources such as wind, solar, and natural gas, achieve energy diversification, promote low-carbon energy consumption, and improve the current energy structure. At the same time, actively introducing CCS storage technology to separate and store carbides from the energy utilization process[10].

Improve energy efficiency and reduce energy intensity. The ways to improve energy efficiency include technological innovation and progress, and investment in energy-saving and emission reduction technologies should be increased[11]. Promote internal industrial upgrading, especially process and technological innovation, to achieve energy conservation and emission reduction goals. In terms of transportation, efforts should be made to avoid large-scale and long-distance transportation of materials and equipment, and to reduce energy consumption and carbon emissions during transportation. The government should actively implement laws and regulations on energy conservation and emission reduction, and improve energy efficiency through legal means.

Establish a carbon emission trading mechanism for the construction industry. At present, carbon emission trading has developed in fields such as electricity, industrial production, and natural gas transportation. By building a carbon emission trading platform for the construction industry, the goal of building energy conservation and emission reduction can be achieved through market mechanisms. On the one hand, building owners can benefit by selling excess carbon emission allowances to the market, enhancing their enthusiasm and initiative in energy conservation and emission reduction. On the other hand, it is conducive to promoting technological reform in enterprises and reducing the increase in costs caused by high emissions.

5 Conclusions

This article focuses on panel data of the construction industry in 11 coastal provinces from 2005 to 2021. Based on the construction of a Tapio based model for decoupling the economic growth and carbon emissions of the construction industry, empirical analysis shows that there is a "weak decoupling expansion coupling weak decoupling strong decoupling" characteristic between the economic growth and carbon emissions of the construction industry in coastal provinces. Among them, Jiangsu, Shanghai, and Zhejiang are in a decoupling state, and low-carbon energy-saving measures have obvious effects. Liaoning, Fujian, and Guangxi have high decoupling elasticity coefficients, and the carbon emissions of the construction industry are severe. The carbon emission control efforts of the construction industry in other provinces need to be strengthened. Using the LMDI decomposition method to analyze the factors affecting decoupling elasticity, it is pointed out that the energy intensity effect is the main factor hindering the decoupling of economic growth and carbon emissions in the construction industry. It is necessary to improve from three aspects: optimizing energy consumption structure, improving energy efficiency, reducing energy intensity, and establishing a carbon emission trading mechanism in the construction industry to achieve the goal of economic growth and low-carbon win-win in the construction industry.

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