# Decomposition of driving factors and analysis of spatio-temporal differences of financial environmental expenditure performance

Yuze Wang[1,*], Yuju Zhang[1], Chenchen Li[1], and Minghui Wang[2]

[1]Business School, Hohai University, No.200 Jinling North Road, Changzhou, Jiangsu, China
[2]Department of Chemistry, Tangshan Normal University, No.156 Jianshe North Road, Tangshan, Hebei, China

**Abstract.** In order to clarify what factors affect the performance of government fiscal environmental protection expenditure from the perspective of " carbon peaking and carbon neutrality " target, and to seek a key path to improve the performance of government fiscal environmental protection expenditure, this paper takes three provinces and one city in the Yangtze River Delta as an example, based on the LMDI model, the environmental protection expenditure performance is decomposed into eight driving factors in three dimensions. The research shows that fiscal environmental protection expenditure effectively promotes regional green development; the fiscal pressure dimension and social development dimension promoted the environmental protection expenditure performance, while the R&D innovation dimension inhibited the regional environmental protection expenditure performance. Among the eight driving factors considered, the effect of fiscal pressure on environmental protection has the strongest promoting effect on environmental protection expenditure performance, and the effect of R&D scale has the strongest inhibiting effect on environmental expenditure performance. At the same time, the temporal evolution trend and spatial characteristics of each factor are significantly different.

## 1 INTRODUCTION

Climate issue is the most severe environmental crisis facing mankind in the 21st century, and has become an unavoidable governance challenge for all governments[1]. On March 5, when delivering the Government Work Report, Premier Li Keqiang pointed out that the government should promote carbon neutrality in an orderly manner, implement the action plan for carbon peaking, and make promoting green and low-carbon development an important task of the government[2]. Local governments have also strengthened their emphasis weight on low-carbon emission reduction factors that is in the process of promoting development, and fiscal expenditure has become a key material guarantee for low-carbon emission reduction work in China.

The Yangtze River Delta region includes three provinces and one city, Jiangsu Province, Anhui Province, Zhejiang Province and Shanghai City; in the period from 2007 to 2020, the average annual growth rate of gross domestic product of the Yangtze River Delta is 8.62%, contributing more than 24% to the national economic growth (measured at constant 2007 prices), and is one of the most economically active regions in the country; however, its economic growth also generates a large amount of carbon emissions, with the total carbon emissions in the Yangtze River Delta region accounting for about 20% of the country's total emissions.[3] To this end, the three provinces and one municipality have incorporated the reduction of carbon dioxide per unit of GDP (carbon emission intensity) into the 14th Five-Year Plan as a binding target. Since 2007, the Ministry of Finance has created a new category of "211 Environmental Protection" in the fiscal pressure classification reform, and renamed it "211 Energy Conservation and Environmental Protection" in 2011.[4] During the period 2007-2020, the average annual growth rate of energy conservation and environmental protection expenditures in the Yangtze River Delta region was 13.78%, which exceeded the growth rate of local general budget expenditures by 11.06%, reflecting the importance the government attaches to energy conservation and environmental protection[5]. To this end, clarifying what factors influence the performance of government energy conservation and environmental protection expenditures in the YRD region[6], and the direction and extent of their effects, can provide theoretical references for seeking key paths to improve the performance of environmental protection expenditures in the YRD region, and can also provide model inspirations for other regions[7].

## 2 MODEL AND DATA

### 2.1 Environmental protection expenditure performance measurement model

The IPCC coefficient method is a method to measure

* Corresponding author: 2063510126@hhu.edu.cn

carbon emissions according to the measurement process and corresponding parameters provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, which uses the product of energy consumption and emission factors as the estimated value of carbon emissions. This paper establishes equation (1) for measuring carbon emissions in each region.

$$C=\sum_{i=1}^{7}\sum_{j=1}^{9}E_{i,j}\cdot H_{i,j}\cdot G_{i,j}\cdot O_{i,j}\cdot\frac{44}{12} \qquad (1)$$

Where $C$ denotes the carbon emissions, the subscript $i$ represents the industry category (agriculture, forestry, animal husbandry and fishery, industry, construction, transportation, storage and postal services, wholesale and retail, accommodation and catering, residential, others), and the subscript $j$ represents the energy category (raw coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, LPG, natural gas). $E_{i,j}$ is the amount of energy consumed by the energy $j$ of industry $i$; $H_{i,j}$ is the average low calorific value of energy $j$ consumed by of the industry $i$; $G_{i,j}$ is the carbon content per unit calorific value of energy $j$ consumed by of the industry $i$; $O_{i,j}$ is the oxidation coefficient of energy consumed by of the industry $i$.

On this basis, the article analyzes the temporal evolution of the carbon emission reduction performance of regional environmental protection expenditures using carbon emission intensity, i.e. carbon emissions undertaken per unit of regional GDP, as an indicator $UGC$; where $UGC$ is the inverse indicator, the smaller the value and the higher the rate of reduction, the better the performance of the region's environmental protection expenditures.

$$UGC=\frac{C}{GDP} \qquad (2)$$

## 2.2 Decomposition model of environmental protection expenditure performance drivers

Drawing on the classical IPAT model, this paper constructs the following equation to decompose the drivers of environmental protection expenditure performance in the YRD regions from three dimensions: financial pressure, R&D innovation and social development.

$$\begin{aligned}UGC=&\frac{C}{HBZC}\cdot\frac{HBZC}{ZC}\cdot\frac{ZC}{SR}\cdot\frac{SR}{R\&D}\\&\cdot\frac{R\&D}{UrbangP}\cdot\frac{UrbangP}{P}\cdot\frac{P}{E}\cdot\frac{E}{GDP}\end{aligned} \qquad (3)$$

Where $C$ represents carbon emissions, $HBZC$ represents local fiscal environmental protection expenditure; $ZC$ represents local general budget expenditure; $SR$ represents local general budget revenue; $R\&D$ represents local internal expenditure on research and experimental development; $UrbangP$ represents regional urban population; $P$ represents regional total population; $E$ represents regional energy consumption (expressed in the amount of standard coal), and $GDP$ is regional GDP.

Also, defining $FP=\frac{C}{HBZC}$ for fiscal environmental protection pressure, $EI=\frac{HBZC}{ZC}$ for environmental protection expenditure intensity, $FB=\frac{ZC}{SR}$ for fiscal balance, $RE=\frac{SR}{R\&D}$ for R&D efficiency, $RS=\frac{R\&D}{UrbangP}$ for R&D scale, $UR=\frac{UrbangP}{P}$ for urbanization, $II=\frac{P}{E}$ for energy input intensity, and $ED=\frac{E}{GDP}$ for energy dependence, equation (3) can be transformed into

$$UGC=FP\cdot EI\cdot FB\cdot RE\cdot RS\cdot UR\cdot II\cdot ED \qquad (4)$$

Thus, introducing the LMDI model, the total change in the environmental protection expenditures performance in the Yangtze River Delta regions can be expressed as follows.

$$\Delta UGC=UGC_t-UGC_0 \qquad (5)$$

$$\begin{aligned}&=\Delta U_{FP}+\Delta U_{EI}+\Delta U_{FB}+\Delta U_{RE}\\&+\Delta U_{RS}+\Delta U_{UR}+\Delta U_{II}+\Delta U_{ED}\end{aligned} \qquad (6)$$

The specific decomposition of each driver can be expressed as follows.

$$\Delta U_{FP}=\frac{UGC_t-UGC_0}{\ln UGC_t-\ln UGC_0}\cdot\ln\left(\frac{FP_t}{FP_0}\right) \qquad (7)$$

$$\Delta U_{EI}=\frac{UGC_t-UGC_0}{\ln UGC_t-\ln UGC_0}\cdot\ln\left(\frac{EI_t}{EI_0}\right) \qquad (8)$$

$$\Delta U_{FB}=\frac{UGC_t-UGC_0}{\ln UGC_t-\ln UGC_0}\cdot\ln\left(\frac{FB_t}{FB_0}\right) \qquad (9)$$

$$\Delta U_{RE}=\frac{UGC_t-UGC_0}{\ln UGC_t-\ln UGC_0}\cdot\ln\left(\frac{RE_t}{RE_0}\right) \qquad (10)$$

$$\Delta U_{RS}=\frac{UGC_t-UGC_0}{\ln UGC_t-\ln UGC_0}\cdot\ln\left(\frac{RS_t}{RS_0}\right) \qquad (11)$$

$$\Delta U_{UR}=\frac{UGC_t-UGC_0}{\ln UGC_t-\ln UGC_0}\cdot\ln\left(\frac{UR_t}{UR_0}\right) \qquad (12)$$

$$\Delta U_{II}=\frac{UGC_t-UGC_0}{\ln UGC_t-\ln UGC_0}\cdot\ln\left(\frac{II_t}{II_0}\right) \qquad (13)$$

$$\Delta U_{ED} = \frac{UGC_t - UGC_0}{\ln UGC_t - \ln UGC_0} \cdot \ln\left(\frac{ED_t}{ED_0}\right) \quad (14)$$

In addition, in order to categorize the drivers conveniently, we divide the eight factors into three dimensions, and the specific results are: the fiscal environmental protection pressure effect, the environmental protection expenditure intensity effect, and the fiscal balance effect belong to the fiscal pressure dimension; the R&D efficiency effect and the R&D scale effect belong to the R&D innovation dimension; the social development dimension includes the urbanization effect, the energy input intensity effect, and the energy dependence effect.

### 2.3 Data sources and description

Since the Ministry of Finance included fiscal expenditure on energy conservation and environmental protection into the government public budget in 2007, the scope of the article is 2007-2020, where each relevant data source and explanation are as follows.

a. The energy consumption data for each year are from the China Energy Statistical Yearbook, and the energy consumption of the raw materials and materials in industry is not included in the calculation because the carbon contained in it is not converted into carbon dioxide in the form of oxidation. In accordance with the coal conversion coefficient published in China Energy Statistics Yearbook, the physical consumption data of various energy sources are converted into 10000 tons of standard coal as the unit of measurement; the values of average low calorific value, carbon content per unit calorific value and oxidation coefficient are obtained from IPCC.

b. Local fiscal environmental protection expenditure data, local general budget expenditure data, local general budget revenue data, $GDP$ data and population data for each province and city were obtained from the China Statistics Bureau; $R\&D$ data were obtained from the China Science and Technology Statistical Yearbook, urban population from the statistical yearbooks of each province; local fiscal environmental protection expenditure data, local general budget expenditure data, local general budget revenue data, $GDP$ data and $R\&D$ data are obtained by deflating the $GDP$ index of each province to 2007 constant prices.

## 3 RESULTS AND ANALYSIS

### 3.1 Environmental protection expenditure performance measurement results

As shown in Figure 1, the article measures the evolution of carbon emission intensity in the three provinces and one city in the Yangtze River Delta from 2007 to 2020 based on equation (1)(2) to measure the performance of fiscal environmental protection expenditure in each region during the research period. Overall, the carbon emission intensity of the three provinces and one city all show a continuous decreasing trend, and it can be considered that the fiscal environmental protection expenditure has effectively promoted the green development of the jurisdictions. However, due to the different economic and social development conditions, the level of carbon emission intensity and the rate of decrease in the three provinces and cities show significant differences. In terms of carbon emission intensity level, Anhui Province has the highest carbon emission intensity, being an important energy exporting province in East China, with a relatively inferior industrial structure, resulting in more prominent pressure on carbon emission reduction. Zhejiang Province has the lowest carbon emission intensity level, and its light industry and service industry account for a larger proportion of the regional GDP and have embarked on a low carbon development path earlier. The carbon emission intensity levels of Shanghai and Jiangsu are similar, and the carbon emission reduction pressure of both of them is in the middle level among the three provinces and one city.

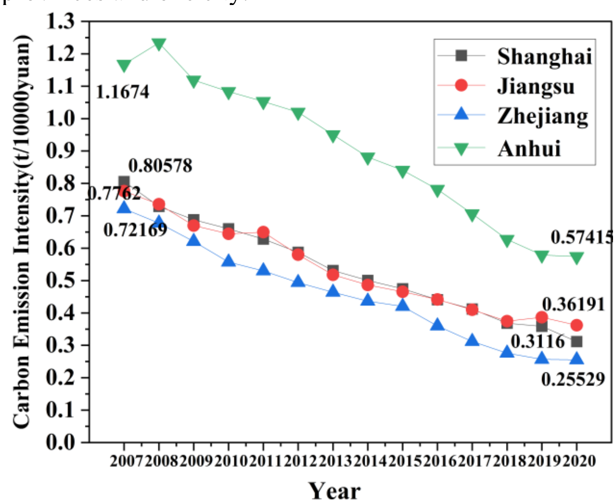


Figure 1. Carbon Emission Intensity of Three Provinces and One City in Yangtze River Delta, 2007-2020

By region, Anhui Province has achieved the most significant reduction in carbon emission intensity over the research period, i.e., among the three provinces and one city, Anhui Province has achieved the most significant results in fiscal environmental protection expenditure. Its carbon emission intensity decreased from 1.1674 tons per million yuan in 2007 to 0.57415 tons per million yuan in 2020, with a cumulative reduction of 0.5933 tons per million yuan, an average annual reduction of 5.31%. The rate of reduction is similar in Jiangsu, Zhejiang and Shanghai, with Shanghai reducing from 0.80578 tons per million yuan in 2007 to 0.3116 tons per million yuan in 2020, a cumulative reduction of 0.4942 tons per million yuan, an average annual reduction of 7.05%; Jiangsu Province reduces its carbon emission intensity from 0.7762 tons per million yuan in 2007 to 0.36191 tons per million yuan, a cumulative reduction of 0.4143 tons per million yuan, an average annual reduction of 7.05%; Zhejiang Province reduces its carbon emission intensity from 0.72169 tons per million yuan in 2007 to 0.25529 tons per million yuan, a cumulative reduction of 0.4664 tons per million yuan, an average annual reduction of 7.68%. With comprehensive analysis of the overall carbon emission intensity level and carbon emission intensity reduction rate, Zhejiang Province can be regarded as a benchmark province for the fiscal energy conservation and emission reduction in the Yangtze River Delta region.

## 3.2 Results of decomposition of environmental protection expenditure performance drivers

### *3.2.1 Results of LMDI decomposition of financial environmental protection expenditure performance by region*

Based on the decomposition equation constructed in Section 3.2 and the relevant formulas of the LMDI model, this paper decomposes the drivers of the evolution of environmental protection expenditure performance in the three provinces and one city in the Yangtze River Delta from 2007 to 2020, with a cumulative reduction in carbon emission intensity of 1.9682 tons per million yuan, and the specific decomposition results are presented in Table 1. Among the three dimensions considered in the research, the fiscal pressure dimension has the strongest contributing effect on the environmental protection expenditure performance, cumulatively reducing the carbon emission intensity by 2.4882 tons per million yuan; among the three factors included in this dimension, the fiscal environmental pressure effect( $\Delta U_{FP}$ ) is the contributing factor, cumulatively reducing the carbon emission intensity by 3.7015 tons per million yuan; while the environmental protection expenditure intensity effect( $\Delta U_{EI}$ ) and the fiscal payment balance effect( $\Delta U_{FB}$ ) are the inhibiting factor, cumulatively increase the carbon emission intensity by 0.8490 tons per million yuan and 0.3643 tons per million yuan, respectively. It shows that the fiscal environmental protection pressure effect pushes the government to increase energy conservation and environmental protection expenditures and innovate the management system of environmental protection expenditures to enhance the efficiency of environmental protection expenditures; while the environmental protection expenditure intensity effect has a negative impact on the performance, indicating that the government fiscal expenditures in the field of carbon emission reduction actually did not fully meet the regional emission reduction demand during the study period; similarly, the fiscal pressure balance degree effect also has a negative impact on the performance of regional environmental protection expenditures, which inhibiting the process of regional carbon emission reduction, in line with Gao Zhengbin [15] et al. and Xi Penghui [16].

Table 1 Results of LMDI decomposition of environmental protection expenditure performance

| Dimensionality | Factors | Shanghai | Jiangsu | Zhejiang | Anhui | Total |
|---|---|---|---|---|---|---|
| Fiscal pressure | $\Delta U_{FP}$ | -1.1612 | -0.9309 | -0.8865 | -0.7229 | -3.7015 |
| | $\Delta U_{EI}$ | 0.5278 | 0.3147 | 0.1737 | -0.1672 | 0.8490 |
| | $\Delta U_{FB}$ | 0.0616 | 0.1302 | 0.1875 | -0.0150 | 0.3643 |
| | Subtotal | -0.5718 | -0.486 | -0.5253 | -0.9051 | -2.4882 |
| R&D Innovation | $\Delta U_{RE}$ | -0.2291 | -0.2702 | -0.2441 | -0.5966 | -1.3400 |
| | $\Delta U_{RS}$ | 0.6916 | 0.7399 | 0.5734 | 1.7081 | 3.7130 |
| | Subtotal | 0.4625 | 0.4697 | 0.3293 | 1.1115 | 2.373 |
| Social Development | $\Delta U_{UR}$ | 0.0044 | 0.1827 | 0.1061 | 0.3829 | 0.6761 |
| | $\Delta U_{II}$ | -0.1210 | 0.0106 | -0.1049 | -0.1028 | -0.3181 |
| | $\Delta U_{ED}$ | -0.2683 | -0.5913 | -0.2716 | -1.0798 | -2.2110 |
| | Subtotal | -0.3849 | -0.398 | -0.2704 | -0.7997 | -1.853 |
| Total | - | -0.4942 | -0.4143 | -0.4664 | -0.5933 | -1.9682 |

The R&D innovation dimension suppresses the performance of regional environmental protection expenditure and has a cumulative effect on raising carbon emission intensity by 2.373 tons per million yuan. Among these, the R&D efficiency effect( $\Delta U_{RE}$ ) cumulatively reduces the carbon emission intensity by 1.34 tons per million yuan, indicating that the environmental protection expenditure effectively stimulates regional green innovation and promotes the technological progress of carbon emission reduction, and thus improves the performance of local environmental protection expenditure; while the R&D scale effect( $\Delta U_{RS}$ ) cumulatively increases the carbon emission intensity by 3.7130 tons per million yuan, which is the strongest factor inhibiting the performance of local environmental protection expenditure among the eight factors considered in this paper, indicating that the government still needs to strengthen its guidance and support for green innovation and development activities.

The social development dimension effectively contributes to the improvement of local fiscal environmental protection expenditure performance, with a cumulative reduction in carbon emission intensity of 1.853 tons per million yuan. Specifically, the

https://doi.org/10.1051/shsconf/202316304030

urbanization effect( $\Delta U_{UR}$ ) suppresses the environmental protection expenditure performance, playing a suppression effect of 0.6761 tons per million yuan; urbanization is accompanied by large-scale urban house and infrastructure construction, which increases the pressure of the government environmental protection. While the energy input intensity effect( $\Delta U_{II}$ ) and the energy dependence effect( $\Delta U_{ED}$ ) are contributing factors to the improvement of environmental protection expenditure performance, reducing carbon emission intensity by 0.3181 tons per million yuan and 2.2110 tons per million yuan, respectively, indicating that in the process of improving the quality of economic development, the dependence on energy consumption is reduced, which in turn alleviates local environmental protection pressure.

### *3.2.2 Comparative analysis of spatial and temporal differences of various factors in different dimensions between regions*

On the basis of the overall LMDI decomposition of fiscal environmental protection performance in Section 4.2.1, in order to further explore the temporal evolution trend and spatial characteristic differences of each influencing factor during the period 2007-2020, the article is expanded by dimension and analyzed year by year.

As shown in Figure 2, in the fiscal pressure dimension, the environmental pressure effect in the three provinces and one city mainly has a positive effect on the environmental protection expenditure performance, and only increases the local carbon emission intensity in some years; meanwhile, the temporal fluctuations of the fiscal environmental protection pressure effect are relatively smooth in Shanghai and Zhejiang Province, while the temporal fluctuations in Jiangsu and Anhui Provinces are obvious. Secondly, the environmental protection expenditure intensity effect has a directional difference across regions: it has a negative effect on fiscal environmental protection performance in Shanghai and Zhejiang Province, while it has a positive effect in Jiangsu Province and Anhui Province. Finally, compared with the first two, the fiscal balance effect has a lower degree of impact and less time-series fluctuations in the three provinces and cities, and the spatial differences are not significant; however, on balance, the fiscal balance effect has a positive impact on local fiscal environmental protection expenditure performance in Anhui Province, while it inhibits local fiscal environmental protection expenditure performance in the other three regions. Overall, the three factors included in the fiscal pressure dimension play the most significant role in improving the fiscal environmental protection expenditure performance in Anhui Province.

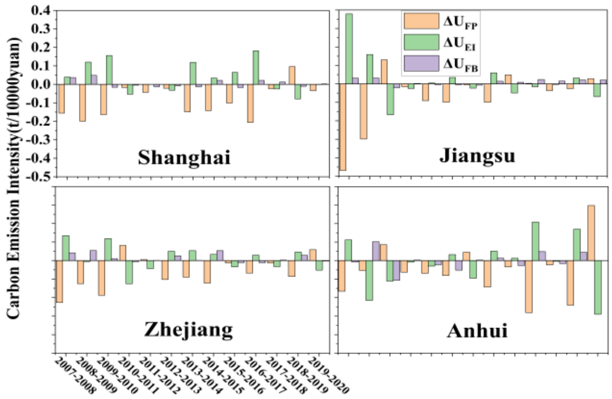


Figure 2. Results of LMDI decomposition of fiscal pressure dimension

As shown in Figure 3, under the R&D innovation dimension, the R&D efficiency effect mainly has a positive impact on the environmental expenditure performance of the three provinces and cities, and the extent of the effect is the deepest in Anhui Province and weakest in Zhejiang Province. In terms of the temporal evolution trend, the R&D efficiency effect shows a fluctuating degree of influence in Shanghai, a weakening trend in Jiangsu and Zhejiang provinces as the year advances, while it shows an increasing trend in Anhui province year by year. In addition, the R&D scale effect mainly suppresses the environmental protection expenditure performance in the three provinces and cities, and the suppression effect is most significant in Anhui Province; however, in terms of time series evolution, the influence degree of the R&D efficiency effect gradually decreases. Overall, compared with the other three regions, Anhui Province has the worst effect of R&D innovation on the fiscal environmental protection expenditure performance, and it still needs the government to strengthen the guidance and support to the provincial enterprises, research institutions and other R&D subjects to carry out green innovation activities.

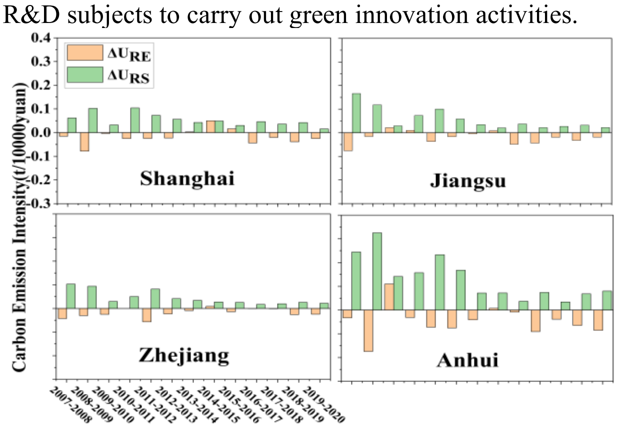


Figure 3. Results of LMDI decomposition of R&D innovation dimension

As shown in Figure 4, under the social development dimension, the urbanization effect mainly suppresses regional fiscal environmental protection expenditure performance, but its suppressive effect gradually diminishes as time progresses, which is related to the rapid progress of urbanization stage into the new urbanization stage in the Yangtze River Delta region; Shanghai is the economic center and financial center of China, and its environmental protection performance is least affected by the urbanization effect among the three provinces and one city; the effect of urbanization is similar to Jiangsu and Zhejiang Province, while the urbanization effect is most profound in Anhui Province. The effects of energy intensity and energy dependence on environmental protection performance fluctuate in Shanghai, while in Jiangsu, Zhejiang and Anhui provinces, these mainly improve the local environmental protection performance, and both have the most significant effect in Anhui province.

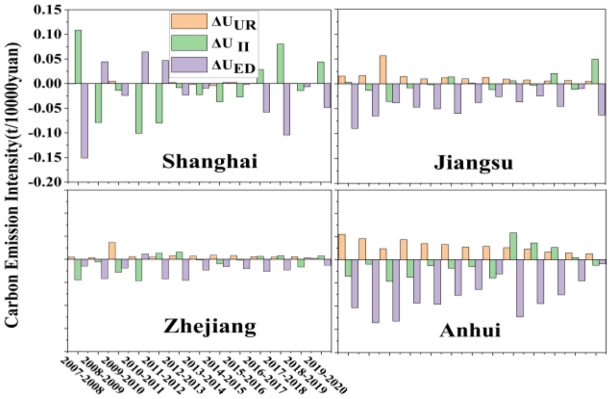


Figure 4. Results of LMDI decomposition of social development dimensions

## 4 CONCLUSION AND RECOMMENDATION

Measuring the government fiscal environmental protection expenditures performance and clarifying what factors affect the government fiscal environmental protection expenditures performance can provide theoretical references for seeking key paths to improve the government fiscal environmental protection expenditures performance and providing policy recommendations to promote local green development. Therefore, this paper takes three provinces and one city in the Yangtze River Delta as the example, selects three dimensions, including fiscal pressure, and eight factors, and conducts a decomposition and spatial and temporal variation analysis of fiscal and environmental protection expenditure performance during 2007-2020 based on the LMDI decomposition model. The following conclusions were obtained.

First, overall, the carbon emission intensity in all three provinces and one city shows a continuous decreasing trend, and it can be considered that the fiscal environmental protection expenditure effectively promotes regional green development; and Anhui Province had the highest carbon emission reduction pressure, while Zhejiang Province had the lowest. Second, the fiscal pressure dimension and social development dimension promote the environmental protection expenditure performance, while the R&D innovation dimension inhibits the environmental protection expenditure performance. Among the eight factors considered in this paper, the fiscal environmental protection pressure effect has the strongest promoting effect on environmental protection expenditure performance, and the R&D scale effect has the strongest inhibiting effect on environmental protection expenditure performance. Meanwhile, there are significant differences in the time-series evolutionary trends and spatial characteristics of the factors.

Based on the above research conclusions, the article proposes the following policy recommendations: first, continue to increase financial support for energy conservation and environmental protection and establish a financial emission reduction fund; meanwhile, actively carry out inter-regional environmental collaborative governance and coordinate financial budgeting efforts in order to improve the efficiency of overall environmental protection funds. Second, encourage R&D and innovation activities about green development, and give the subsidies of energy conservation and emission reduction and Supporting talent support to relevant enterprises, in order to promote technological innovation and optimize regional energy and industrial structures. At the same time, the government can optimize the supervision channels of the public, such as building government affairs channels to meet the needs of the public, so that the public can more conveniently participate in the whole process of the government's carbon reduction work.

## References

1. UN EnvironmentProgramme. Emissions Gap Report 2020[EB/OL]. [2022-12-26]. http://www.unep.org/emissions-gap-report-2020.
2. China government website. Premier Li Keqiang's report on the work of the government (text abstract)_ Prime Minister_ China government website [EB/OL]. [2022-12-26]. http://www.gov.cn/premier/2022-03/05/content_5677248.htm.
3. Suzuki S, Nijkamp P. Winners in the urban champions league – A performance assessment of Japanese cities by means of dynamic and super-efficient DEA[J]. Journal of Urban Management, 2018,7(1):6-20.
4. Montmartin B, Herrera M. Internal and external effects of R&D subsidies and fiscal incentives: Empirical evidence using spatial dynamic panel models[J]. Research Policy, 2015,44(5):1065-1079.
5. Li G, Guo F, Di D. Regional competition, environmental decentralization, and target selection of local governments[J]. Science of The Total Environment, 2021,755:142536.
6. Chen K, Kou M, Fu X. Evaluation of multi-period regional R&D efficiency: An application of dynamic DEA to China's regional R&D systems[J]. Omega, 2018,74:103-114.
7. Dabuo F T, Du J, Madzikanda B, et al. Influence of research and development, environmental regulation, and consumption of energy on CO2 emissions in China—novel spatial Durbin model perspective[J]. Environmental Science and Pollution Research, 2022.