Synergistic Effect of Pollutant and Carbon Reduction in Tianjin Based on the Emission Reduction Elastic Coefficient Method

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Abstract: In order to quantitatively evaluate the synergistic effect of pollutant and carbon reduction in Tianjin during the 13th Five Year Plan period, this study adopts the emission factor method to calculate Tianjin's air pollution equivalent and greenhouse gas emissions during the period. At the same time, the emission reduction elasticity coefficient method is used to evaluate the synergistic effect of pollutant and carbon reduction. The results showed that the main sources of air pollution equivalent and greenhouse gas emissions were industrial sources during the 13th Five Year Plan period in Tianjin. The air pollution equivalent had a high degree of correlation with the sources of greenhouse gases. There would be synergistic effects in reducing pollution and carbon in Tianjin from 2016 to 2017, but there was no synergistic effect in reducing pollution and carbon in Tianjin from 2018 to 2020. During the 13th Five Year Plan period in Tianjin, overall pollution reduction and carbon reduction would not have a synergistic effect. To achieve synergy in reducing pollution and carbon, Tianjin needed to promote a continuous decline in the total amount of greenhouse gases.

1. Introduction

During the 13th Five Year Plan period in Tianjin, the pollution prevention and control battle has achieved remarkable results, and the ecological environment has been significantly improved. During the 13th Five Year Plan period, Tianjin's main air pollutants and carbon emission intensity have both been reduced. However, the 2021 National Ecological Environmental Protection Work Conference pointed out that the ecological environmental protection work has entered a new stage of coordinated governance of pollutant and carbon reduction. Not only the intensity of carbon emissions, the total amount of carbon emissions should also be reduced. Achieving the synergistic effect of reducing pollution and carbon has become a goal requirement for in-depth fight against pollution. The synergistic effect is derived from the accompanying benefits proposed by Ayers et al [1]. The accompanying benefits are proposed to illustrate that the emission reduction measures of carbon dioxide and other greenhouse gases can reduce the production of other pollutants. Since then, IPCC[2] formally put forward the concept of synergistic effect in the third assessment report. Synergistic effect refers to the phenomenon that the implementation of a certain pollutant emission reduction measure achieves this pollutant emission reduction while also producing other environmental benefits. Foreign research on the synergistic effect of pollutant and carbon reduction started early [3]. The technical methods and research applications are relatively mature [4]. Although domestic research on the synergistic effect of pollutant and carbon reduction starts relatively late, it has developed rapidly. Judging from the development of the past ten years, the research on the synergistic effect of pollutant and carbon reduction has made great progress in departments [5], regions [6] and methods [7]. At present, no scholar has evaluated the synergistic effect of pollutant and carbon reduction in Tianjin during the 13th Five Year Plan period. In order to understand the synergistic effect of pollutant and carbon reduction in Tianjin during the 13th Five Year Plan period, the emission reduction elasticity coefficient method is used to evaluate the synergistic effect of pollutant and carbon reduction in Tianjin during the 13th Five Year Plan period.

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2. Research methods and data sources

2.1. Emission source classification

According to the "Technical Manual for Preparation of Discharge Inventory of Urban Air Pollution Sources", air pollution sources are generally divided into ten categories: fossil fuel stationary combustion sources, mobile sources, process sources, solvent use sources, dust sources, agricultural sources, biomass combustion sources, waste treatment sources, storage and transportation sources, and other emission sources[8]. These ten types of sources can be further subdivided according to the pollutant generation mechanism and emission characteristics. According to "Guidelines for the Preparation of Provincial Greenhouse Gas Inventories (for Trial Implementation)", Greenhouse gas emission sources are generally divided into five categories: energy activities, agriculture, industrial production processes, land-use change and forestry, and waste disposal. Among them, energy activities can be further divided into fossil fuel combustion, biomass combustion, coal mining and post-mining activities escape, and oil and natural gas system escape. In order to coordinate with the analysis of air pollutant emissions, the study only accounts for direct emissions of greenhouse gases, and does not account for the transfer of electricity and forest carbon sinks. In order to facilitate collaborative analysis, the first-level sources are classified into industrial sources, traffic sources, construction sources, agricultural sources, living sources, and centralized pollution control facilities[9].

2.2. Emissions accounting

The emission of air pollutants is calculated in accordance with the "Technical Manual for Compilation of Urban Air Pollution Source Emission Inventory", and the main accounting formula is as follows (1):

$$E = A \times EF \times (1-\eta) \tag{1}$$

In the formula, E stands for the amount of air pollutant emissions, A stands for fuel consumption or product output or administrative area activity level, EF stands for the pollutant generation factor, and η stands for the removal efficiency of pollutants by pollution control facilities.

In this research, "carbon" refers to greenhouse gases. Greenhouse gas emissions are calculated in accordance with the "Guidelines for the Preparation of Provincial Greenhouse Gas Inventories (Trial)".

2.3. Air pollution equivalent accounting

The definition of air pollution equivalent is derived from the "Environmental Protection Tax Law of the People's Republic of China", and the following formula (2) is used to calculate the air pollution equivalent:

$$E_{LAP} = \alpha E_{SO2} + \beta E_{NOX} + \gamma E_{CO} + \delta E_{VOCs} + \varepsilon E_{NH3} + \zeta E_{PM10} \tag{2}$$

In the formula, E_{LAP} stands for the air pollution equivalent and the unit is t, E_{SO2} stands for sulfur dioxide emissions and the unit is t, E_{NOX} stands for the amount of nitrogen oxide emissions and the unit is t, E_{CO} stands for the amount of carbon monoxide emissions and the unit is t, E_{VOCs} stands for emissions of volatile organic compounds and the unit is t, E_{NH3} stands for ammonia emissions and the unit is t, and E_{PM10} stands for the emission of inhalable particulate matter and the unit is t. α, β, γ, δ, ε, and ζ are the equivalent coefficients of sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds, ammonia, and inhalable particulate matter, respectively, which are dimensionless. The specific values of the equivalent coefficient are shown in Table 1 below.

Table 1. Air pollution equivalent coefficient table for conversion of air pollutants

Atmospheric Pollutant	Equivalent Coefficient Value	Equivalence Factor
Sulfur Dioxide	1/0.95	α
Nitrogen Oxides	1/0.95	β
Carbon Monoxide	1/16.7	γ
Volatile Organic Compounds	1/0.95	δ
Ammonia	1/9.09	ε
Inhalable Particulate Matter	1/2.18	ζ

2.4. Synergy coefficient

The synergistic coefficient of pollutant and carbon reduction can quantitatively describe the synergistic emission reduction effect of greenhouse gases and air pollution. The commonly used coefficient is the elasticity coefficient of emission reduction. The specific calculation formula is shown in the following formula (3):

$$s = \frac{\Delta E_{co2} / E_{co2}}{\Delta E_{LAP} / E_{LAP}} \tag{3}$$

In the formula, S stands for the synergy coefficient and dimensionless, ΔE_{CO2} stands for the amount of greenhouse gas emission reduction and the unit is t, E_{CO2} stands for the amount of greenhouse gas emissions and the unit is t. ΔE_{LAP} stands for the equivalent emission reduction of air pollution and the unit is t. E_{LAP} stands for the equivalent emission of air pollution and the unit is t.

When $S \leq 0$, it means that there is no synergy in reducing pollution and carbon. When $S>0$, it means that pollution reduction and carbon reduction are synergistic. When $0<S<1$, it means that the reduction effect on air pollutants is greater than the reduction effect on greenhouse gases such as carbon dioxide. When $S=1$, it means that the reduction of greenhouse gases and air pollutants is equivalent. When $S>1$, it means that the effect of reducing greenhouse gas emissions is greater than that of reducing atmospheric pollutants [10-11].

2.5. Data sources

Energy sources data are derived from the "6-2 Tianjin Energy Balance Sheet" in the "China Energy Statistical Yearbook" over the years. The GDP is derived from the "Statistical Bulletin of National Economic and Social Development of Tianjin" over the years. The sown area of crops, the output of agricultural products, the output of major industrial products, the building area, the number of motor vehicles, the catering industry data, the total population, the energy consumption and other data come from Tianjin Statistical Yearbook over the years.

3. Results and analysis

3.1. Correlation analysis

The study calculated the air pollution equivalent and greenhouse gas emissions of Tianjin from 2016 to 2020, and calculated the contribution rate of each emission source. The results are shown in Figure 1. It can be seen from Figure 1 that the main emission sources of air pollution equivalent and greenhouse gases are industrial sources. The proportion of industrial sources equivalent to air pollution ranges from 58.6 to 65.3%, and it is decreasing year by year. The result shows that during the "Thirteenth Five-Year Plan" period, the air pollution control measures adopted by Tianjin City have effectively prevented air pollution from industrial sources. The proportion of industrial sources of greenhouse gases ranges from 82.0% to 83.1%, which is basically stable. This shows that during the "Thirteenth Five-Year Plan" period, Tianjin's greenhouse gas emission structure has not undergone significant changes.

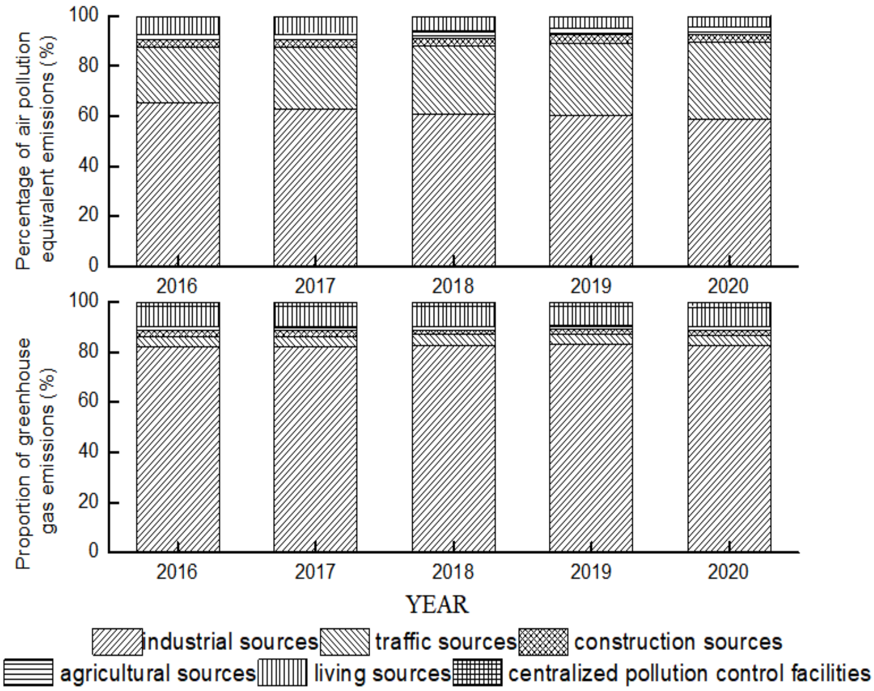

Fig. 1. Tianjin's air pollution equivalent and greenhouse gas emissions from 2016 to 2020

Table 2. Correlation analysis of sources of air pollutants and greenhouse gases from 2016 to 2020

	Sulfur dioxide	Nitrogen oxides	Carbon monoxide	Volatile Organic Compounds	ammonia	Inhalable particulate matter	Air pollution equivalent	carbon dioxide	Methane	Nitrous Oxide	greenhouse gas
Sulfur dioxide	1	0.579	.978**	.972**	-0.06	.922**	.929**	.988**	0.335	.957**	.986**
Nitrogen oxides	0.579	1	0.604	0.647	-0.16	0.787	.823*	0.565	-0.077	0.521	0.559
Carbon monoxide	.978**	0.604	1	.998**	0.003	.905*	.948**	.997**	0.428	.989**	.997**
Volatile Organic Compounds	.972**	0.647	.998**	1	-0.01	.922**	.964**	.992**	0.396	.982**	.992**
ammonia	-0.06	-0.16	0.003	-0.01	1	-0.241	-0.083	-0.016	0.245	0.131	-0.007
Inhalable particulate matter	.922**	0.787	.905*	.922**	-0.241	1	.967**	.903*	0.048	.844*	.897*
Air pollution equivalent	.929**	.823*	.948**	.964**	-0.083	.967**	1	.933**	0.238	.905*	.930**
carbon dioxide	.988**	0.565	.997**	.992**	-0.016	.903*	.933**	1	0.414	.986**	1.000**
Methane	0.335	-0.077	0.428	0.396	0.245	0.048	0.238	0.414	1	0.485	0.428
Nitrous Oxide	.957**	0.521	.989**	.982**	0.131	.844*	.905*	.986**	0.485	1	.988**
greenhouse gas	.986**	0.559	.997**	.992**	-0.007	.897*	.930**	1.000**	0.428	.988**	1

In order to understand the correlation degree of each emission source category, the correlation between various air pollutants and various greenhouse gases from 2016 to 2020 was analyzed, and the results are shown in Table 2. It can be seen from Table 2 that sulfur dioxide, carbon monoxide, volatile organic compounds, inhalable particulate matter, air pollution equivalent, carbon dioxide, nitrous oxide and greenhouse gases all have a high correlation with each other. Nitrogen oxides only have a high correlation with air pollution equivalent. Ammonia has the highest correlation with methane. The Pearson correlation coefficient between air pollution equivalent and greenhouse gases is 0.930 ($P<0.01$). This shows that the air pollution equivalent has a high correlation with greenhouse gases. From the perspective of the correlation analysis of emission sources, both air pollution and greenhouse gas emission sources are industrial sources. It has the characteristics of having the same root. This is consistent with the results of Wang Jinnan et al. [12].

3.2. Synergy Effect in Tianjin

Based on the 2016-2020 air pollution equivalent and greenhouse gas emissions and annual emission reductions, the Tianjin Municipality's "Thirteenth Five-Year Plan" period will be used to calculate the synergy coefficient of pollutant and carbon reduction. The results show that the synergistic coefficients of pollutant and carbon reduction in Tianjin from 2016 to 2020 are 0.25, 0.26, -0.23, -0.54, -0.12, with an average of -0.08. Therefore, from 2016 to 2017, Tianjin's pollution reduction and carbon reduction have a synergistic effect. The pollutant and carbon reduction measures implemented by Tianjin have a greater effect on the reduction of air pollutants than the reduction of greenhouse gases. There will be no synergistic effect in reducing pollution and carbon in Tianjin from 2018 to 2020. From the perspective of the entire "13th Five-Year Plan" period, there is no synergistic effect in reducing pollution and carbon in Tianjin. From the perspective of air pollution emission, the total emission of air pollutants decreases year by year from 2016 to 2020. The greenhouse gas will decrease year by year from 2016 to 2017, and increase year by year from 2018 to 2020. This is due to the increase in greenhouse gas emissions leading to the lack of synergy in pollutant and carbon reduction in Tianjin from 2018 to 2020. This shows that under the influence of Tianjin's "Air Pollution Prevention and Control Action Plan", air pollution equivalent and greenhouse gases have entered a stage of synergy in pollutant and carbon reduction during 2016-2017. However, from 2018 to 2020, Tianjin will be affected by changes in the international situation and the new crown epidemic, especially the impact of the Sino-US trade war. In order to slow down the lack of economic growth in Tianjin, the consumption of energy and resources increased slightly. This in turn leads to an increase in greenhouse gas emissions and there is no longer a synergistic effect in pollutant and carbon reduction in Tianjin. Therefore, in order to achieve synergy in pollutant and carbon reduction, Tianjin needs to promote a continuous decline in the total amount of greenhouse gases [13-14].

3.3. Uncertainty analysis

The emission factors used to calculate the air pollution equivalent and greenhouse gas emissions are from the "Technical Manual for Preparation of Discharge Inventory of Urban Air Pollution Source" and "Guidelines for the Preparation of Provincial Greenhouse Gas Inventories (for Trial Implementation)", respectively. These two technical manuals are for the whole country, and the localized emission factors of Tianjin are not taken into consideration. The calculation results will bring certain uncertainty.

4. Conclusion

During the 13th Five Year Plan period in Tianjin, the sources of air pollution equivalent and greenhouse gas emissions were industrial sources. The Pearson correlation coefficient between air pollution equivalent and greenhouse gas emission sources is 0.930 ($P<0.01$). The result shows that the air pollution equivalent has a high correlation with the source of greenhouse gases.

From 2016 to 2017, Tianjin's pollution reduction and carbon reduction have a synergistic effect, and the pollution reduction and carbon reduction measures implemented by Tianjin have a greater effect on the reduction of air pollutants than the reduction of greenhouse gases. There will be no synergistic effect in reducing pollution and carbon in Tianjin from 2018 to 2020. From the perspective of the entire "13th Five-Year Plan" period, there is no synergistic effect in reducing pollution and carbon in Tianjin. In order to achieve synergy in reducing pollution and carbon, Tianjin needs to continue to promote the reduction of total greenhouse gas..

References

[1] AYRES R U, WALTER J. The greenhouse effect: damages, costs and abatement[J]. Environmental and resource economics, 1991, 1(3): 237-270.

[2] IPCC. Climate Change 2001-Mitigation[R]. Cambridge: Cambridge University Press, 2001.

[3] ZHENG J J, SUN X, ZHANG M Y, et al. Review of researches on the synergistic effect of GHGs mitigation and air pollution control at home and abroad [J]. Ecological Economy, 2015, 31(11): 133-137.

[4] Smith K R, Haigler E. Co-benefi ts of climate mitigation and health protection in energy systems: scoping methods [J]. Annu Rev Public Health, 2008, 29: 11-25.

[5] Zhang Y, Liu L C, Cao D. Synergistical emission control of carbon dioxide and conventional pollutants in thermal power plants [J]. Thermal Power Generation, 2013, 42(9):63-65.

[6] MA D, CHEN W Y. Analysis of the co-benefit of emission reduction measures in China's iron and steel industry[J]. China Environmental Science, 2015, 35(1): 298-303.

[7] JIA L Y, WANG Y H, WANG K, et al. Evaluation of carbon dioxide coordination emission reduction based on national air pollution control plan[J]. Environmental Protection Science, 2020, 46(6): 19-26.

[8] Wang Jinnan, Ning Miao, Yan Gang, et al. Implementing Climate-friendly Strategy for Air Pollution Prevention and Control[J]. China Soft Science Magazine, 2010(10): 28-36,111.

[9] Umar M, Ji X, Kirikkaleli D, et al. Environmental cost of natural resources utilization and economic growth: can China shift some burden through globalization for sustainable development?[J]. Sustainable Development, 2020, 28(6): 1678-1688.

[10] Rafique M Z, Nadeem A M, Xia W, et al. Does economic complexity matter for environmental sustainability? Using ecological footprint as an indicator[J]. Environment, Development and Sustainability, 2022, 24(4): 4623-4640.

[11] Ahmed Z, Asghar M M, Malik M N, et al. Moving towards a sustainable environment: the dynamic linkage between natural resources, human capital, urbanization, economic growth, and ecological footprint in China[J]. Resources Policy, 2020, 67: 101677.

[12] Alsayegh M F, Abdul Rahman R, Homayoun S. Corporate economic, environmental, and social sustainability performance transformation through ESG disclosure[J]. Sustainability, 2020, 12(9): 3910.

[13] Demena B A, Afesorgbor S K. The effect of FDI on environmental emissions: Evidence from a meta-analysis [J]. Energy Policy, 2020, 138: 111192.

[14] Khan S A R, Yu Z, Belhadi A, et al. Investigating the effects of renewable energy on international trade and environmental quality[J]. Journal of Environmental management, 2020, 272: 111089.