Relationship verification between CO_2 and pollutant emissions: policy evaluation based on the pollutant discharge fee in China

Siping Ji, Haiyun Chen, Yongming Chuan, Libin Gao, Chenhui Liu, Hongqin Liu and Wendai Lv

ABSTRACT

Serious environmental problems are exacerbated with economic growth. Pollution control and emission reduction are now challenged, and we have to pay real attention. Pollutant discharge fee (PDF), one of the enforced levy regulations on pollutant discharge in China, was introduced in a new perspective as a direct economic representation of multi-pollutant emission. The DPSIR framework and regression model were constructed to analyze the co-control process of pollutant emission based on the provincial data from 2000 to 2012. The results showed that PDF had a significant and positive relationship with CO_2 emission in China during 2000–2012. A special contradiction was found that CO_2 emission and PDF increased greatly, verified with empirical analysis, while the pollutant emission reduction target in the 11th and 12th Five-Year Plan (FYP) was achieved for the corresponding periods, which indicated that emission co-control is still unrealized in China. Conversely, the single indicator control of pollutant emission generated by opportunistic behavior of the Chinese government failed to bring real environmental improvement. In addition, PDF can be seen as a mirror for the Environment Tax (ET) to achieve authentic emission reduction and pollution control, even for sustainable development in China.

Key words | CO_2 emission, co-control, pollutant discharge fee (PDF), pollutant emissions

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INTRODUCTION

There is both worsening international and regional environmental pressure besetting China resulting from global climate change and local pollution aggravation (Liang *et al.* 2016). Furthermore, China is the biggest contributor to energy consumption and greenhouse gas (GHG) production in the world (IEA 2009; Zhang *et al.* 2011; Li *et al.* 2013; Wang *et al.* 2017). Water pollution (Matos *et al.* 2014) (including groundwater) and heavy metal consumption are a challenge to varying degrees (Han *et al.* 2016; Liu *et al.* 2016), with more than 1.6 million Chinese people dying prematurely by air pollution in 2012 (Rohde & Muller 2015). It is a fact that the government must take responsibility for emission control and reduction to further contribute to sustainable development.

Currently, the Chinese government is promulgating the 13th Five-Year Plan (FYP) to advance sustainable development continuously. The report pointed out that local energy consumption will be controlled to 5 billion tons of standard coal, and the allowable emission is to be 2,001 million tons of chemical oxygen demand (COD), 207 million tons of ammonia nitrogen, 207 million tons of ammonia nitrogen, and 1,574 million tons of NO_x, falling to 10%, 10%, 15%, and 15%, respectively, compared with 2015 (The State Council of the People's Republic of China 2016). In order to

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guarantee and support those targets, many subsidiary policies have been introduced and implemented, such as domestic carbon trading market establishment (National Development & Reform Commission of the People's Republic of China 2011, 2014a, 2014b, 2016; Jotzo & Löschel 2014). However, these current policies mostly use a similar assessment standard of emission reduction, a single indicator, to control pollutants, which incurs bottlenecks (Siping et al. 2019). On the premise of economic growth, resource consumption and environmental pollution have existed for a long period in China, thus efficient environmental sustainability in a co-controlled way needs to be importantly taken into account. Accelerated implementation of pollutant emission co-control is stringent in the process of sustainable development with different kinds of emission reduction measures, and is an urgent mission for policymakers (Liang et al. 2016; Zeng et al. 2017).

Co-control in the literature is mostly established with relevant eco-routes, including policies and strategies, to achieve emission reduction for climate change, environmental management, and sustainable development (Jiang et al. 2016; Karim et al. 2017; Liu et al. 2017). In China, many studies have implied the concept of co-control for environmental protection and management (Mao et al. 2014). Examples include Ren et al. (2012), who evaluated pollutant emissions and health impacts based on the inter-city passenger transport perspective in Shenyang. Zeng et al. (2017) demonstrated that a co-control plan had an obvious advantage on the air pollutant control economy in Urumqi. However, the above studies mainly focused on air pollutant perspective, emphasizing the relationship between CO_2 and air pollutant emission reduction. Indeed, relevant analysis has revealed that CO_2 emitted is usually accompanied by large amounts of other pollutants (Liang et al. 2016; Zhou et al. 2016; Guo et al. 2017). Thus, challenges on environmental sustainability have still existed, especially for more broad pollution control and emission reduction. Also, the situation offers a unique opportunity to find out and ascertain the gap between economic growth and environmental benefits, and efforts should be made towards emission reduction in different spatial and temporal characteristics (Zhang et al. 2016; Zeng et al. 2017; Zhou et al. 2017).

An advanced emission reduction approach should integrate a variety of pollutants together, and pollutant emission monetization characterization, the pollutant discharge fee (PDF), is a proper mediator and worthy of more attention, because the pollutant emission economic measure plays a key role in this process. For example, a coal power plant will produce CO_2, SO_2, NO_x, dust emissions. Adopting an emission reduction policy for the goal of the 13th FYP, enterprise will focus on the reduction of emission costs. When sewage cost is higher than treatment investment and operation cost, the behavior of pollutants' emission to the environment would rise, resulting in the discharge fee becoming a priority option.

This paper fills a gap to avoid the disadvantages of single indicator assessment by employing the PDF, and focusing on CO_2 and other emissions. Then, the DPSIR framework and regression model are constructed to analyze the co-control process. Despite Environment Tax (ET) in China being implemented formally in 2018, both of them are dependent on the amount of the individual pollutant emission. Thus, PDF can be used as a multi-pollutant emission economic measure nowadays, also to reveal the pollutant emission situation in spatiotemporal trends and economic effectiveness. Lastly, emission reduction policy validity for sustainable development is evaluated in our research.

METHODOLOGY AND DATA

Research framework

This paper examines the correlation of CO_2 emissions and pollutant emissions, aiming to assess the emission reduction effect with a theoretical model and empirical test against the background of the implementation of national policies during 2000–2012. This research focuses on the following aspects: incorporating CO_2 emissions and other pollutant emissions together based on the PDF, revealing their endogeny, subsequently doing the relevant analysis, and then evaluating the effects of current policies of pollution control and emission reduction. Also, problems are discussed. Last, an advanced co-control plan is proposed within the perspective of the PDF, and its effectiveness in the future is looked forward to.

Driver–Pressure–State–Impact–Response (DPSIR) framework

The DPSIR framework has been recognized as the facilitating skill to find and solve different kinds of impacts which are related to the numerous aspects of ecosystem (Tsuzuki 2015), and is transformed from the original Pressure–State–Response (PSR) framework (OECD 1993). Furthermore, five submodules, driver, pressure, state, impact, and response, are taken into the process of flow evaluation from a socioeconomic development and environment point of view (Kelble et al. 2013). Today, it has become the appropriate tool for policymakers and researchers to identify and assess environmental trends, make environmental decisions and for management (Song & Frostell 2012).

The DPSIR model offers a general flow to identify and evaluate the economic outcomes and population behavior as with drivers (D) in the ecosystem first, further environmental quality pressure (P) will be created, which can lead to a change of its former status (S), and then form the loop. After that, people forcedly respond (R) based on the corresponding feedback from the ecosystem. Then, a series of environment and society policies will be set or adjusted to respond to the above influences, which refers to human behavior influence (I)). This model focuses on the staggered interacting flows for development issues both from social economy and environment, and emphasizes input and output flows with their feedback of the overall system. Based on this advanced method, ecosystems can be evaluated better with corresponding key indicators (Sun et al. 2016). Thus, the DPSIR framework is an efficient paradigm that is qualified to identify the correlations between PDF and CO_2 emission, and more importantly, which also creates a systematic root to find out the causes, analyze the consequences of environment and economy, and propose the responses to their changes (Santos-Martín et al. 2013; Hou et al. 2014).

Regression model

The regression model is one of the major quantitative methods to test factors' correlation based on quantitative analysis. Based on the concept and connotation of symbiosis theory and DPSIR framework analysis, the relationship between CO_2 emissions and PDF is derived. Then, a regression model is used to examine the correlation with empirical data. The regression model is established as follows:

$$PDF = \alpha_0 + \alpha_1 CE \tag{1}$$

where, CE represents CO_2 emission.

At the same time, the significant correlation between pollutant emissions and economic development has been confirmed (Wang et al. 2016), and GDP is the best evaluating index for the economic development. Therefore, it can be concluded that the PDF is affected by the fluctuation of GDP, and then the control variable is taken into account in the regression model:

$$PDF = \alpha_0 + \alpha_1 CE + \alpha_2 GDP \tag{2}$$

Considering PDF, GDP, and CE are trend variables, regression models are adjusted as follows (Equation (3)) to avoid spurious regression:

$$\begin{aligned} t(PDF_{i+1} - PDF_i) &= \alpha_0 + \alpha_1 s(CE_{i+1} - CE_i) \\ &\quad + \alpha_2 m(GDP_{i+1} - GDP_i); \\ if\ PDF_{i+1} - PDF_i \geq 0,\ t = 1;\ CE_{i+1} - CE_i \geq 0,& \\ s = 1;\ GDP_{i+1} - GDP_i \geq 0,\ m = 1;& \\ PDF_{i+1} - PDF_i < 0,\ t = -1;\ CE_{i+1} - CE_i < 0,& \\ s = -1;\ GDP_{i+1} - GDP_i < 0,\ m = -1;& \end{aligned} \tag{3}$$

where i means the year, PDF_i is the pollution discharge fees in i year, CE_i is the CO_2 emissions in i year, GDP_i is the GDP in i year. $PDF_{i+1} - PDF_i$ represents the increment of pollution discharge fees from i to $i+1$, similarly for $CE_{i+1} - CE_i$ and $GDP_{i+1} - GDP_i$. The coefficients t, s, and m are used to get the absolute values for the reason that the key things we are focusing on are the variations instead of change directions.

Data sources

The correlation between CO_2 emissions and PDF in China from 2000 to 2012 is analyzed through a regression model with panel data. On one hand, considering the price adjustment of the PDF during 2013 to 2015, to ensure the consistency and reliability of data, a sample period is decided. On the other hand, there are data measure differences between the Ministry of Environmental Protection (MEP) of China and the National Bureau of Statistics of China (NBS). Further, the PDF data during 2000–2012 were published by the former, while the latter covered 2000–2015, thus, there is a discrepancy in the two data sources. In order to guarantee the accuracy of the PDF value, we adopt the value of PDF from the MEP. Last, in view of influences and consequences from emission reduction in the 12th FYP, the sample period is extended from 2010 to 2012. The specific sources of data are shown in Table 1.

RESULTS

Correlation analysis between PDF and CO_2 emission based on DPSIR

Except for quantitative analysis adopted in the social and nature sciences, DPSIR framework promises clarity regarding the complex environment issues addressed (Ness *et al.* 2010; Bell 2012; Gregory *et al.* 2013). In view of its obvious advantages in integrating knowledge across various disciplines and concepts, different decisions are made. The DPSIR framework as well as its application is deemed as a bridge connecting scientific disciplines and policy and management (Svarstad *et al.* 2008; Tscherning *et al.* 2012). The DPSIR framework is used to deduce the role of the PDF in the process of environment management and emission reduction as seen in Figure 1.

Table 1 | Data source

Variable	Data source
PDF	The Ministry of Environmental Protection (MEP)
CO_2 emission	China Emission Accounts and Datasets (CEADs)
GDP	National Bureau of Statistics of the People's Republic of China

Driving forces

The traditional model of China's economy is facing a great challenge from environmental pollution, which requires update of the growth structures as soon as possible, getting rid of the large resource consumption and pollutant emissions. The majority of the above activities are directly linked to emissions, mainly caused by the expansion model of economic development as well as current policy, such as population size, economy, socio-politics, science, technology, and culture (CBD 2003). All of these have been considered as the powers and roots for human development for a long time.

Pressure

Global climate change is taking place and intensifying because of GHG emissions greater than any period in history (Lewison *et al.* 2016). The emissions of GHGs have gradually changed the composition of the Earth's atmospheric environment, leading to global warming. As well, pollutant emissions have increased sharply accompanied by CO_2 emissions and are explained by excessive resource consumption. These kinds of complex situations may influence future global climate change and other environment issues as well (Steffen *et al.* 2003).

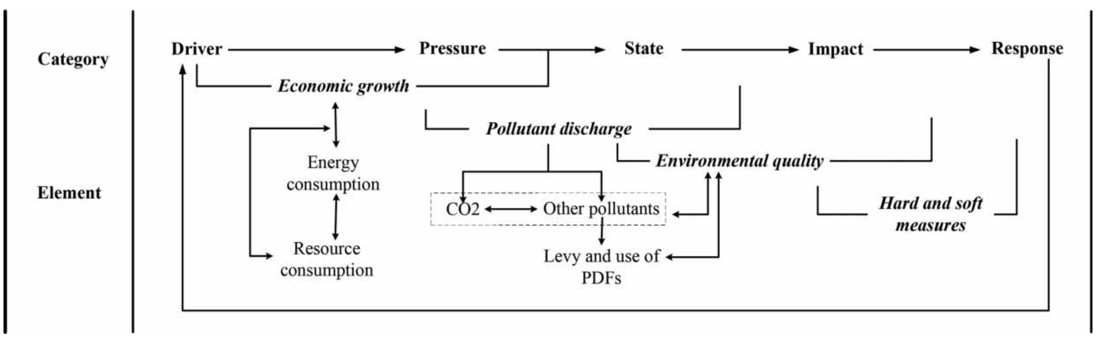

Figure 1 | The DPSIR framework based on the PDF.

State

In the process of rapid economic development, large quantities of resources and non-renewable fuels (especially coal) have been consumed, which result in a dramatic increase of air pollutants, leading to serious air pollution now (Kan *et al.* 2012). Meanwhile, a series of emissions enter into the environment, accompanying energy and resource consumption, such as waste water, solid waste, etc. Even if it plays an important role in waste treatment, the mode of end of pipe (EOP) creates transfer of pollutants, although the target pollutant emissions' reduction has been achieved, especially in China today. The local and regional environmental issues are also receiving increasing attention.

Impact and response

PDFs are levied by the country's regional governments to effectively stimulate enterprises to reduce emissions and improve environmental quality. Moreover, the PDF remains one of the best economic indexes for pollutant emissions, and along with coordinating the symbiosis between CO_2 and those pollutants, the syntropy and synchronous changes of fluctuation can be concluded from the DPSIR framework.

Descriptive statistical analysis

In the descriptive statistics (Table 2), the maximum value of the PDF (2,873.43 million yuan) was in Shanxi in 2007; in contrast, the PDF of Xizang in 2003 reached the minimum value (3.570 million yuan). Great differences of PDFs in different provinces can be drawn from the standard deviations, which means huge pollutant emission differences existed in various provinces correspondingly. Similarly, there was a big gap of CO_2 emissions in different provinces, and the maximum value was in Shandong in 2012 and the opposite in Ningxia in 2000. It was also found that the GDP of Shandong in 2012 ranked third in China, and CO_2 emissions were correlated with GDP to a certain extent.

Table 2 | Descriptive statistic

	Minimum	Maximum	Average	Standard deviation
PDF (million yuan)	3.570	2,873.430	441.095	448.093
GDP (billion yuan)	11.780	5,706.792	890.007	948.158
CO_2 emission (million ton)	0.814	1,007.560	214.521	178.263

Although the provincial value of PDFs was not in accordance with CO_2 emissions, both kept on increasing (Figure 2). Further, growth of PDFs accelerated from 2004 and then slowed down until 2009, which maintained a certain synchronization with CO_2 emission growth. In addition, the restructure effectively driven by the economic mode improvement of energy structure and emission reduction effectiveness during 2011–2015 (Zhou *et al.* 2016), itself reflected the change trends of PDF and CO_2 emission. Combined with the GDP change trend, the speed of GDP increased yearly and surpassed CO_2 emission from 2003. This revealed the development route and direction of China's low carbon economy, indicating that China's economic development started changing and was established without sacrificing the environment and natural resources.

Correlation analysis

Based on the descriptive statistical analysis, correlation analysis is introduced to make further analysis of the relationship between PDF and CO_2 emission. The Pearson correlation result between $t(PDF_{i+1} - PDF_i)$ and $s(CE_{i+1} - CE_i)$ was 0.314 (Table 3), indicating that PDFs were correlated positively and significantly with CO_2 emissions at 0.05 significant level, which verified the initial demonstration of theoretical deduction in the DPSIR model.

Regression analysis

Regression results are shown in Table 4. The model results proved that CO_2 emissions were correlated with PDF significantly (Sig. is 0.000) at 0.05 significance level in the period from 2000 to 2012 when GDP was taken as a control variable, and regression coefficient was 0.987, meaning a positive relationship existed, which also supported the symbiotic coordination between CO_2 emissions and pollutant emissions again. The regression coefficient of CO_2 emissions

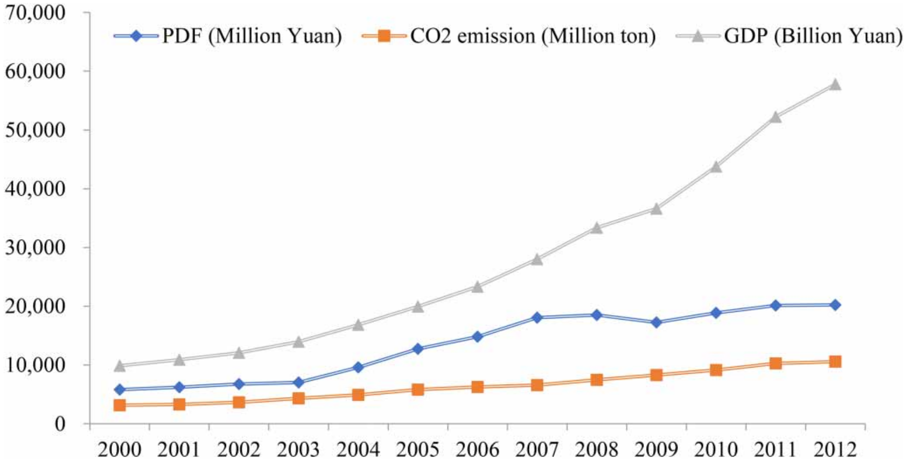

Figure 2 | The trend of national PDF, CO_2 emission, and GDP from 2000 to 2012.

Table 3 | Correlation analysis

		$t(PDF_{i+1} - PDF_i)$	$m(GDP_{i+1} - GDP_i)$	$s(CE_{i+1} - CE_i)$
$t(PDF_{i+1} - PDF_i)$	Pearson correlation	**1.000**		
	Sig. (two-tailed)			
	Case number	367		
$m(GDP_{i+1} - GDP_i)$	Pearson correlation	0.198**	**1.000**	
	Sig. (two-tailed)	0.000		
	Case number	367	372	
$s(CE_{i+1} - CE_i)$	Pearson correlation	0.314**	0.317**	**1.000**
	Sig. (two-tailed)	0.000	0.000	
	Case number	360	360	360

Table 4 | Regression analysis

Model	B	t	Sig.	VIF
α_0	31.1523	3.8163	0.0002	
$m\ (GDP_{i+1} - GDP_i)$	0.0835	1.9022	0.0579	1.1117
$s\ (CE_{i+1} - CE_i)$	0.9870	5.3595	0.0000	1.1117
ANOVA				
F	21.5684			
Sig.	0.0000			
Durbin–Watson	1.5604			
Adjust R-squared (%)	10.3000			

was 0.987, that is to say, 1% of CO_2 emissions increasing could produce 0.987% of rise in PDF. Our preliminary data suggested that CO_2 emissions were related to PDF significantly at the provincial level, especially thinking of economic development. Based on the above empirical analysis, the concurrent conclusion that the strong positive correlation between CO_2 emissions and PDF, as we just demonstrated with the DPSIR framework, is obtained.

On the one hand, the real fluctuating trend of CO_2 emissions and PDF was consistent with empirical results that the total amount of CO_2 emissions continued to increase and PDF increased accordingly. On the other hand, the increase of CO_2 emissions led to a rise in PDF, and therefore it is easy to predict that national pollutant emissions were still increasing simultaneously. However, the pollutant emission reduction had been achieved for those pollutants that required assessment in the 11th and 12th FYP. The analysis results of the above aspects were obviously contradictory. Thus, we draw the conclusion that emissions of those specific pollutants which were involved in the emission reduction targets did decrease, but other pollutants (not in the emission reduction targets) or new pollutant emission increase was produced reflected in the growth of PDF. Due to the emission reduction accomplished via EOP mode, the multi-pollutant emission control strategy was not in reality in China, thus, PDF and CO_2 emissions shown a consistent fluctuation at this stage. Emission reduction evaluation did not genuinely realize the pollutant co-control but just the single indicator control, which could not produce the emission reduction of general objectives effectively, and thus it was only the transfer from specific pollutants to other pollutants.

Policy implication

After using the DPSIR framework to conduct correlation deduction between other pollutant emissions and CO_2 emissions by introducing PDF as the characterization of pollutant change trend on the basis of co-control theoretical analysis, in combination with provincial data related to PDF and CO_2 emissions from 2000 to 2012 in China, the relationship between PDF and CO_2 emissions was tested utilizing the above empirical model. The co-control analysis and the discussion of the pollutant emission reduction based on PDFs were conducted reasonably with the analytical framework constructed in this study.

The results of the above empirical study on the correlation of PDF and CO_2 emissions showed that PDFs had a significant positive relationship with CO_2 emissions based on the provincial data, even though GDP was considered. The significance of correlation was enhanced with more stringent environmental requirements' implementation in China, which was confirmed with CO_2 emission and GDP, indicating initially the realization of an ecologically civilized society. The positive relationship existed during the whole study period, 2000–2012, that was the time before and after implementation of the energy reduction policy beginning with the 12th FYP (2011–2015).

The special contradiction of PDF increasing and pollutant emission reduction in the 11th and 12th FYP targets was significantly verified with empirical analysis; theoretical analysis results based on the DPSIR framework with co-control of pollutant emissions had not been validated through empirical examination. Conversely, increasing of the PDF indicated the emission of pollutants went up as well as CO_2 emissions with the combination of collaborative symbiosis while pollutant emission reduction was achieved in the 11th and 12th FYP, for example, the decline of SO_2 emissions was 14% until 2010, more than the reduction target of 10% proposed in the 12th FYP. Pollutant emissions with a co-control plan were still unfulfilled in China, the current situation just being the single indicator control, and emissions were not taken as a group in decision-making. More linkage targets for multiple pollutants must be put into future FYPs. Combining with the regional disparity, pollutant emissions and CO_2 emission characteristics should be seriously considered (Mao *et al.* 2012). That is, the above emission spillovers will further promote opportunity behavior in the field of emission control and emission reduction. To respond to the special contradiction, the design of the future pollutant emission co-control policies is critical to encourage authentic pollution control and emission reduction (Dong & Liang 2014).

CONCLUSIONS AND FUTURE RESEARCH DIRECTION

Conclusions

According to our research results, the correlation between CO_2 emissions and other pollutant emissions was verified with the DPSIR framework and empirical analysis, and the pollutant emission co-control policies were put forward in China to avoid single indicator task, which will not lead to real atmospheric contamination control. To address the issue of CO_2 and other emissions from the co-control perspective, we propose the following:

1. The energy structure should be continuously promoted both from coal power at peak and energy structure adjustment to address CO_2 emissions. Meanwhile, accelerate more accurate and pragmatic measures implementation, taking pollutants as a group to design the most effective abatement routes for emission reduction.
2. Different forms of environmental discharges are spread throughout the whole processes of production, consumption, and treatment. To solve this issue not only relies on cleaner production process, but also requires discovery

and exploration of a pollution treatment process technique, which follows the principles of simple operation, cost-efficiency, less energy, and chemical utilization and eco-safety. On the other hand, more advanced analysis and evaluation, such as material flow management, also needs further promotion, both by national and regional governments.

The future research direction

Our thesis is to analyze the target opportunity for achieving environmental sustainability beginning with research of the correlation between PDF and CO_2 emissions based on co-control with the DPSIR framework under the circumstance of FYPs' energy saving and emission reduction. PDF is used as an economic means for pollutant emissions, and the significant relationship between PDF and CO_2 emissions was confirmed in the results of empirical tests. Results showed that reduction policy targets realized are just a kind of single indicator goal without considering co-control reduction for a sustainable environment, and provided the opportunity to achieve the desired targets in the short term for the national and regional government, at the expense of the environment in fact.

Recommendations for future research are:

1. How to construct a complete, all-round and multi-target integrated system for national states so as to accomplish real emission reduction. The ET entered into force to replace the PDF in 2018, and that also creates an issue: the coverage area of pollutants is similar for ET and PDF, therefore to achieve emission co-control, more research needs to be done. As well, ET is also a good indicator of the environmental status, which should receive more attention in future research.
2. The experience and deficiency of the PDF can be considered for ET implementation. Co-control should also be taken seriously, especially during the construction of the carbon trade market. Also, it can serve as a measure of emission control and supervision for enterprises in view of the microeconomic entity.
3. China needs to accelerate the upgrade of industry, implement cleaner energy policy, and reform the traditional environment treatment mode to a green one to achieve real sustainable development.

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