

Article

Research on the Impact of Market-Based Environmental Regulation Policies on Ecological Pressure: Evidence from China's Carbon Emissions Trading Pilot

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Abstract: In the process of China's path to modernization, the concept of harmonious coexistence between man and nature has become increasingly prominent. In the dual context of the development of human society and the improvement of ecological wellbeing, how to reasonably exert environmental regulation policies to actively address the problem of ecological overload has become an important challenge that we need to face urgently. Therefore, based on the panel data of 30 provinces in China from 2005 to 2021, this paper uses the three-dimensional ecological footprint model to evaluate the degree of interference of human activities on the ecological level and selects the difference-in-differences model to examine the impact of external policy shocks, namely, a carbon emissions trading pilot (CETP) policy, on ecological pressure and its transmission mechanism. The results show that moderate government intervention, unified market regulation, and positive industrial response jointly enhance the mitigation effect of CETP on ecological pressure. In areas with strong environmental regulation and a high level of green credit, the incentive effect of the carbon trading mechanism is more significant. In the context of the transformation from industrial civilization to ecological civilization, the findings provide practical guidance and paths for how regions and enterprises can effectively respond to CETP and how governments, markets, and industries can jointly reduce the ecological pressure on the environment.

Keywords: carbon trading; ecological pressure; harmonious coexistence between man and nature; ecological sustainable development



Academic Editors: Roberto Mancinelli and Antonio Caggiano

Received: 11 December 2024

Revised: 24 January 2025

Accepted: 11 February 2025

Published: 22 February 2025

Citation: Wang, Y.; Meng, D.; Li, L.; Wang, Y. Research on the Impact of Market-Based Environmental Regulation Policies on Ecological Pressure: Evidence from China's Carbon Emissions Trading Pilot. *Sustainability* **2025**, *17*, 1872. <https://doi.org/10.3390/su17051872>

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1. Introduction

In the new journey of China's path to modernization, ecological sustainability as a new requirement for development is a major concern in China. With the rapid development of the economy after the country's reform and opening up, China's environmental pollution is in a high incidence trend, and a labor-intensive production mode has caused the problem of ecological environmental pressure to be particularly prominent. The 20th National Congress of the Communist Party of China pointed out that it is necessary to improve the institutional system of ecological civilization and take the harmonious coexistence of man and nature as the essential requirement of Chinese-style modernization. Since the 18th National Congress of the Communist Party of China, the leap-forward development of renewable energy and the adjustment of the energy structure have made remarkable achievements in ecological

governance. However, regarding ecological development, while continuously promoting pollution control is important, it is also crucial to alleviate the pressure of human activities on the environment and even help the coordinated development of man and nature.

As a critical element in the development of the ecological civilization framework, the carbon trading market significantly contributes to the mitigation of global climate change and the construction of a beautiful China. It represents a pivotal policy instrument for China's pursuit of the "double carbon goal". By assigning a monetary value to carbon emissions, the market stimulates enterprises to implement emission reduction initiatives and facilitate the transition of the economy towards greener and low-carbon pathways. Consequently, it encourages businesses to seek economic profits while simultaneously prioritizing environmental conservation, thereby fostering a synergistic relationship between economic and ecological benefits. During China's evolution towards an ecological civilization, the carbon trading market initially established a market system characterized by both constraints and incentives, mediated through mechanisms such as total quantity control and carbon pricing. This system drives the transformation and upgrading of enterprises, stimulates the growth of renewable energy, and optimizes the energy structure. Utilizing a market-oriented ecological compensation mechanism, it advances the preservation and restoration of ecosystems, aids China in achieving more comprehensive sustainable development objectives, and makes a substantial contribution to the nation's ecological civilization construction. The allowance calculation employs the benchmark method, which restricts the carbon dioxide emissions per unit of product. Other carbon emission trading mechanisms also include products such as CCER (China Certified Emission Reduction) and are conducted through methods like agreement transfer and one-way bidding. In 2013, online transactions were gradually launched in Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Hubei, and Shenzhen. By February 2024, China's carbon emission trading market covered annual carbon dioxide emissions of about 5.1 billion tons, including 2257 key emission units, making it the world's largest carbon market covering greenhouse gas emissions. With the continuous expansion of the ranks of enterprises, CETP has become the key to promoting the construction of a green circular low-carbon industrial system and reducing the ecological pressure of human activities [1,2].

The research on CETP and the ecological environment is increasing and mainly focuses on the following three aspects. (1) The policy effect of CETP—Studies have shown that the implementation of CETP can significantly reduce the total amount and intensity of carbon dioxide emissions, and its synergistic emission reduction effect has also reduced other air pollutants such as sulfur dioxide [3,4]. At the same time, scholars have actively explored the emission reduction mechanism of the policy and concluded that the reduction in energy consumption, scientific and technological innovation, and industrial structure upgrades are the key paths for the policy to achieve positive effects in different regions. Based on the pilot characteristics of the policy, relevant studies have further verified its spatial spillover effect in promoting carbon emission reductions in adjacent areas [5–8]. (2) Related literature on ecological pressure—Ecological pressure is predominantly quantified through three primary methodologies: the multi-level index system approach, thermodynamic methods, and material accounting techniques. In contrast to the former two, the ecological footprint model, as a material accounting method, circumvents the subjectivity inherent in weight assignment and the loss of dimensionless information from raw data, thereby yielding more reliable data when assessing ecological pressure [2–4]. The ecological footprint theory was initially conceptualized by Canadian William Rees and his doctoral student Mathis Wackernagel in the early 20th century [2–4]. This theory gauges the impact of human activities on the ecological environment by determining the area of ecologically productive land required to sustain human consumption. Given its close correlation with the high

degree of unity of ecological pressure, it serves as a proxy indicator for ecological pressure measurement. Existing literature also concentrates on analyzing the driving forces behind ecological pressure. Researchers employ the ordinary least squares (OLS) method or Tobit model to investigate the causes of ecological pressure and quantify the significance of various driving factors, such as economic development, income levels, and marketization degree [5,6], in order to explore the current state of the ecological environment across different regions and identify core influencing factors to address resource and environmental challenges. In recent years, the scope of ecological pressure research has continued to expand, evolving from the initial national level to encompass provincial, municipal, township, and specific industrial sectors. The research content has also transitioned from static analysis to dynamic measurement. An increasing number of studies have focused on the temporal trends of the ecological footprint and its implications for sustainable development, providing a scientific foundation for formulating effective environmental management and sustainable development strategies [6–8]. (3) The impact of CETP on the ecological environment—Scholars generally take enterprises, being the main body of carbon emission reduction responsibility, as the research object; discuss the impact of CETP on the green efficiency of enterprises; and point out that although the radiation range of CETP in different cities is different, it can indeed promote the low-carbon transformation of urban industry and the growth of the total factor productivity of enterprises [9–13]. Seeking this benefit, scholars have conducted more in-depth discussions on how the CETP extends the green effect of enterprises to the ecological environment's efficiency and other related issues. Among them, key industries in carbon emission reductions, such as the construction and electric vehicle industries, have been the focus of scholars because of their high carbon emissions and high usage characteristics, respectively. Scholars have begun to find ways to achieve carbon neutrality in construction and establish carbon emission assessment models for electric vehicles to explore the low-carbon transformation paths of the two industries [6,14].

The extant literature is relatively extensive, yet several gaps remain to be addressed. Firstly, the existing research on carbon trading policies predominantly focuses on the direct effects of these policies, such as their reduction in the total volume and intensity of carbon dioxide emissions as well as their synergistic emission reduction effects on other air pollutants like sulfur dioxide. However, there is a relative scarcity of discussions regarding the extended effects of carbon trading policies on ecological pressure. Current studies primarily employ rudimentary statistical methods, such as ordinary least squares (OLS) or Tobit models, to analyze the causes of ecological pressure, with limited application of advanced econometric models, resulting in lower credibility of the findings. Research on the impact of carbon trading on ecological development is mostly grounded in industrial subjects, and the ways in which carbon trading policies affect ecological pressure through multiple subjects and multi-level mechanisms warrant further exploration.

Therefore, addressing the issues present in the existing research, such as incomplete exploration of policy effects, simplistic econometric model foundations, and singular research subjects, and in order to scientifically and accurately assess the impact of carbon trading policies on ecological pressure, this paper takes 30 provinces and cities in China as the research subjects. Based on the ecological footprint theory and beginning with the three key dimensions of government, industry, and market, it employs a difference-in-differences model to explore the specific pathways through which carbon trading policies promote the harmonious coexistence of humans and nature.

The marginal contributions of this paper are as follows. First, this paper provides for the first time empirical evidence for CETP in alleviating ecological pressure and supplements the relevant research on the impact of CETP on the ecological environment.

At the same time, the ecological environment is the foundation of human survival and development. Therefore, to a certain extent, it also describes the relationship between the two and fills the research gap on the impact of human social development on the ecological environment. Second, the theoretical framework is supplemented. Different from the existing research based on the industrial subject and the internal mechanism of the industry to explore the relationship between CETP and industrial green development, this paper explores the direct impact of policy on the ecological environment and combines the characteristics of market-based environmental regulation policy to analyze the relationship between CETP and ecological pressure and its connection mechanism from three levels: direct policy impact, unified market regulation, and positive industry response. Third, the research horizon is updated. From the dual perspective of ecology and economics, this paper comprehensively uses the three-dimensional ecological footprint model and the difference-in-differences model to provide a more comprehensive and reliable analysis framework for the impact of CETP on ecological pressure, thus providing policy makers with a more scientific basis for decision making.

2. Research Methods and Data

2.1. Theoretical Analysis

Based on the nature of environmental public goods and the scarcity of their capacity, problems such as the abuse of natural resources and excessive environmental pollution have emerged in an endless stream [15,16]. Reducing the burden of environmental pollution requires both government intervention in corporate pollution behavior and market-oriented tools for the effective allocation of ecological resources [16]. As a market-based environmental regulation, CETP combines government intervention and market mechanisms. First, the main body of policy release, that is, government supervision, curbs the rent-seeking behavior of rights holders to occupy environmental resources through non-competitive means such as bribery and data tampering [17,18], which in turn reduces the breeding of social inequality, in which resources and interests are concentrated in a few enterprises, and gives full play to the fairness and effectiveness of ecological environment governance to reduce the vicious nuisance of human beings to the environment and help people and nature coexist harmoniously. Second, the policy uses market attributes to set economic incentives for greenhouse gas emissions, prompting companies to actively seek sustainable development solutions for the rational allocation of innovative technologies and resources for emission reductions under cost-effectiveness [19,20]. At the same time, the CETP mechanism can guide capital to flow to green projects and renewable energy through the spread of price signals in the carbon market and further resolve the intrusion of human activities on the ecological environment. In summary, this study proposes:

Hypothesis 1: *CETP will reduce the ecological pressure.*

According to the externality theory of the neoclassical school, CETP can be regarded as an external trimming mechanism, which uses the market to price the negative environmental externalities of the production behavior of the enterprise and then forces the enterprise to incorporate environmental costs into management decisions [21–24]. Thus, the environmental costs of the enterprise are internalized, CO₂ emissions are reduced, and ecological pressure is alleviated. On the one hand, CETP encourages enterprises to fulfill their emission reduction responsibilities and sell the remaining carbon emissions to other enterprises for additional economic benefits. Under this economic incentive mechanism, enterprises actively reduce carbon emissions and achieve win–win integration of environmental protection and economic benefits [23–26]. On the other hand, in order to complete

emission reduction tasks, enterprises may need to purchase carbon emissions from the market. This means that companies need to pay an additional fee to solve their own carbon over-emissions problems. In order to reduce costs and maximize profits, companies will adopt more environmentally friendly production measures to reduce carbon dioxide emissions. The increase in temperature, changes in precipitation pattern, and the rise of sea levels caused by carbon emission are reduced, which alleviates the negative impact on habitat conditions [27]. Therefore, the decrease in carbon emissions improves the stability of the ecosystem and reduces the ecological pressure. In summary, this study proposes:

Hypothesis 2: *CETP directly reduces CO₂ emissions in order to ease the ecological pressure.*

Local market segmentation mainly refers to the behavior of local governments within a country to restrict the entry of foreign resources into the local market or restrict the flow of local resources to the foreign market through administrative control means for the sake of local interests [18,19]. As a market-based environmental regulation, the segmentation of CETP undoubtedly limits the free flow and rational allocation of market factors and induces the phenomenon of regional information asymmetry, which makes the advantage of the “scale dividend” disappear. At the same time, when market segmentation occurs, the role of the CETP operation system and incentive mechanism is weakened, and it is difficult for carbon price signals to be transmitted among regions, resulting in a reduction in the willingness of industries to reduce carbon emissions and a reduction in the number of resources inclined to low-carbon technologies and sustainable practices [21], thus exacerbating the environmental pressure caused by industrial pollution. In summary, this study proposes:

Hypothesis 3: *Market segmentation reduces the mitigation effect of CETP on ecological pressure.*

The change in carbon emissions shown by the carbon peak is a “Kuznets curve” that continues to rise from fast to slow until the annual growth rate is zero and then continues to decline. In the stage of carbon emission decline, industry needs to use carbon sinks and carbon capture technology for carbon recovery behavior to finally achieve carbon neutralization. Therefore, industrial science and technology innovation is an important supporting factor for achieving this process [22–24]. Specifically, based on the modernization of harmonious coexistence between humans and nature, industry can promote innovation-driven strategies from both source transformation and end-of-pipeline governance. In the transformation of the source, China can actively get rid of the trade mode of replacing intangible technical resources with tangible assets and turn to the innovation-driven mode characterized by intensive and green development of endogenous growth resources to cut off the production mode of resource loss and ecological destruction at the starting point [25]. In terms of end-of-pipeline treatment, industry can dynamically track key indicators of the ecosystem in real time by deploying advanced intelligent monitoring systems such as sensor networks and remote sensing technologies and then use integrated data-driven models to predict and evaluate indicator changes. Before the spread of pollutants and the degradation of ecosystems, potential problems can be identified in time and corresponding remediation measures can be implemented [26,27]. Therefore, a high level of technological innovation is conducive to the rapid achievement of the scientific and technological standards required by the CETP in industry, thereby reducing the ecological pressure.

The carbon trading market stimulates low-carbon technological innovation within industry and also promotes efficient inter-industry aggregation to enhance the resilience of the green industry chain. However, intensive production modes, over-exploitation of resources, and increased greenhouse gas emissions brought about by industrial agglomera-

tion have led to very different results than expected [28–30]. This agglomeration effect not only promotes the development of industry but also makes the development of industrial productivity exceed the absorptive capacity of the resources and environment itself, and the ecosystem has been overloaded with the carrying capacity of resources and environment for a long time. Specifically, with the deepening of industrial agglomeration, competition among enterprises has intensified, and environmental protection and sustainable use of resources have been neglected in the pursuit of short-term economic benefits [31,32]. In this context, although the implementation of CETP has promoted carbon emission reductions through market mechanisms, its mitigation effect on ecological pressure is relatively limited [33–35]. In summary, this study proposes:

Hypothesis 4: *The innovation behavior within industry will increase the inhibitory effect of CETP on ecological pressure, while the agglomeration behavior between industries will weaken the inhibitory effect of CETP on ecological pressure.*

Based on the above, the impact mechanism of CETP on ecological pressure is shown in Figure 1.

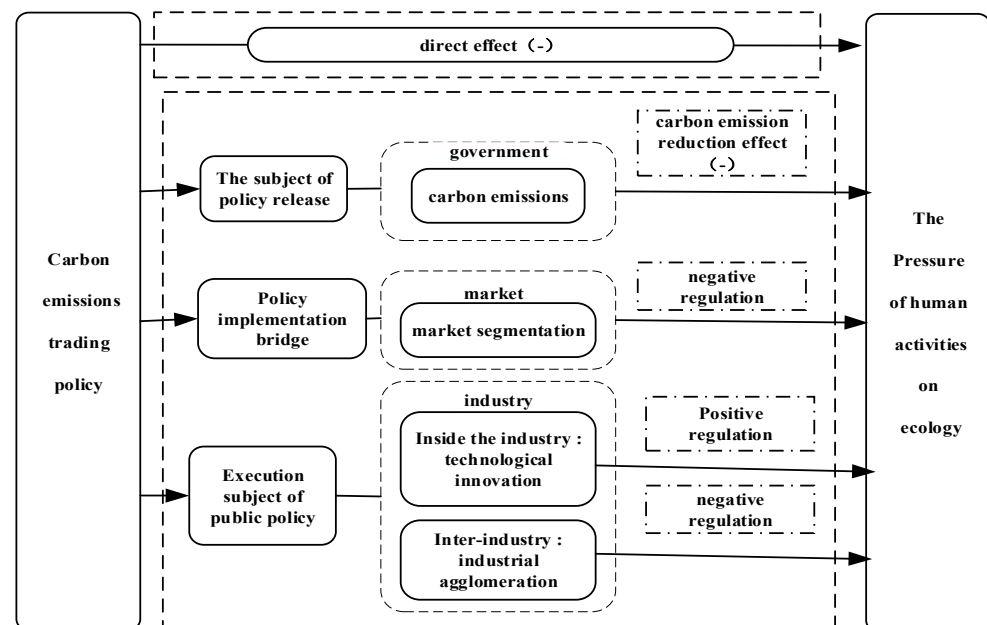


Figure 1. Action mechanism frame diagram.

2.2. Research Methods

2.2.1. Baseline Regression Model

In order to verify the reduction effect of CETP on ecological pressure, the difference-in-differences model is constructed as follows:

$$\ln EF_{it} = \delta_0 + \beta_1 did_{it} + \beta_X X_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where i represents the regional variable, t represents the time variable, and the explained variable $\ln EF_{it}$ represents the ecological pressure level of the year t in the region i , for which the logarithmic treatment is taken; $did_{it} = treat_i \times T_t$ is the core explanatory variable; and $treat_i$ represents the policy dummy variable. If area i is a pilot area of CETP, the value is 1; otherwise, the value is 0. T_t is the variable of policy time node. If CETP has been implemented in year t , the value is 1. If CETP has not been implemented in year t , the value is 0. X_{it} denotes the set of control variables. β_1 is the coefficient of policy effect, and

the estimated coefficient of each control variable is represented by β_X . η_i is the fixed effect of province, γ_t is the annual fixed effect, and ε_{it} is the disturbance term.

2.2.2. Three-Dimensional Ecological Footprint Model

The three-dimensional ecological footprint model provides a more comprehensive assessment of ecological pressure and the encroachment of human activities on the ecological environment by incorporating the dimensions of footprint breadth, footprint depth, and footprint time. Footprint breadth signifies the actual occupation of ecologically productive land area by human activities, reflecting the extent of human appropriation of natural resource flows. It encompasses a diverse array of ecologically productive land types, such as arable land, forest land, and water bodies. By quantifying the area of these lands occupied by human activities, it can intuitively demonstrate the degree of human reliance on natural resources and the direct impact on ecosystems. The larger the footprint, the more extensive the area occupied by human activities within ecosystems, the higher the demand for natural resource flows, and the greater the pressure exerted on ecosystems. Footprint depth gauges the intensity of natural resource consumption by human activities, that is, the long-term impact of human activities on ecosystems. It focuses on the appropriation consumption of natural resource stocks by human activities, reflecting the degree of threat posed by human activities to the sustainability of ecosystems. The greater the depth of the footprint, the more humans encroach upon the stock of natural resources, and the deeper the intrusion into ecosystems, potentially leading to the degradation of ecosystem functions and the reduction of biodiversity. The temporal dimension of the footprint considers the trajectory of the ecological footprint over time. By analyzing the dynamic changes in the ecological footprint, the long-term impact and sustainability of human activities on ecosystems can be assessed. It concentrates on the variations in the ecological footprint across different time periods, revealing whether the impact of human activities on ecosystems continues to intensify, stabilize, or alleviate. In summary, the three-dimensional ecological footprint model can accurately quantify the level of ecological pressure and evaluate the impact of human activities on the ecological environment. Specifically, the ecological footprint method converts various types of biological resource indicators and energy indicators into corresponding bio-productive land in a certain proportion and calculates the total area of bio-productive land capable of continuously providing resources or assimilating waste in a three-step process.

Regarding energy ecological footprint calculation, from the perspective of the carbon cycle, the definition of the fossil energy ecological footprint is revised from “forest area used to absorb greenhouse gas emissions from fossil energy combustion” to “forest and grassland area used to absorb greenhouse gas emissions from fossil energy combustion”. On the basis of estimating the absorption ratio of the two, the fossil energy ecological footprint is calculated and used to replace the land area of various energy sources:

$$A_{ce} = \frac{C_{ce} \times H_{ce} \times Cd_{ce} \times Per_f}{\overline{EP}_f} + \frac{C_{ce} \times H_{ce} \times Cd_{ce} \times Per_g}{\overline{EP}_g} \quad (2)$$

Among them, A_{ce} is the ecological footprint of fossil energy; C_{ce} is the consumption of fossil energy; H_{ce} is the combustion calorific value coefficient of fossil energy; Cd_{ce} is the carbon emission coefficient of energy; Per_f is the share of carbon absorbed by forests; Per_g is the share of carbon absorbed by grassland; $\overline{EP}_f$ is the average global forest carbon absorption capacity; and $\overline{EP}_g$ is the average global forest carbon absorption capacity.

Regarding equilibrium factor calculation, based on the output, area, and calorific value of 39 kinds of bio-energy covered by five land types in the ecological footprint

model accounting system, the parameter adjustment indexes that can help the horizontal comparison of different ecological conditions are constructed:

$$q_i = \frac{\bar{E}_i}{\bar{E}} = \frac{E_i}{A_i} / \frac{E}{A} = \frac{\sum_j p_i^j x_j}{A_i} / \frac{\sum_i \sum_j p_i^j x_j}{\sum_i A_i} \quad (3)$$

Among them, q_i is the equilibrium factor of the type of land i in the province; $\bar{E}_i$ refers to the average production capacity of class i land; $\bar{E}$ is the average production capacity of all land in the province; E_i is the total biological yield of type i land; A_i is the biological production area of type i land; p_i^j is the product yield of the j species of the type of land i ; and x_j is the product yield of the j species.

Regarding ecological footprint calculation, the human impact on the Earth's ecosystems and environment can be calculated by using the area of land and water to estimate the human occupation of various resources in order to maintain their own survival:

$$EF = \sum_{i=1}^4 q_i \times \frac{c_i}{p_i} \quad (4)$$

In the formula, EF is the ecological footprint; q_i is the equilibrium factor of the type of land i ; c_i is the per capita consumption of all products of Class i land; and p_i is the yield per unit area of type i land.

2.3. Variable Selection

2.3.1. Dependent Variable

In this paper, the per capita ecological footprint variable is used as the explained variable. The three-dimensional ecological footprint model is selected to measure the five aspects of cultivated land, grassland, forest land, water area, and fossil energy land, and it is used to characterize the pressure caused by human activities on the ecological environment [31]. The ecological footprint model accounting system is listed in Table 1.

Table 1. The bioenergy data selected for the ecological footprint model.

Types of Land	Biological Production/Energy Consumption
Cultivated land	Rice, wheat, corn, beans, potatoes, cotton, oil, hemp, beets, sugar cane, tobacco, vegetables, pork, eggs
Grassland	Beef, mutton, milk, wool, cashmere
Forest land	Tea, honey, fruit, wood, rubber, tung seed oil, tea seed oil
Waters	Fish, shrimps, crabs, shellfish, algae
Fossil energy land	Coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil, natural gas
Construction land	Electricity

2.3.2. Core Explanatory Variables

The core explanatory variable (DiD) is the cross term of the dummy variable of the CETP and its time node variable. Considering that the policy was promulgated in 2011 and gradually implemented in 2012 and 2013, this paper sets the policy implementation year as 2013, and the implementation areas are Beijing, Tianjin, Shanghai, Guangdong, Chongqing, and Hubei. Since Shenzhen is located in Guangdong Province, it is no longer used as a separate pilot unit, and the data are merged in Guangdong Province.

2.3.3. Mechanism Variable

- (1) Carbon emissions (CO_2) are quantified by the aggregate volume of CO_2 emissions at the provincial level as reported in the statistical yearbook.

- (2) The market segmentation index (MS) refers to the practice of local governments within a nation restricting the influx of external resources into the local market or impeding the outflow of local resources to external markets through administrative controls in pursuit of local interests [18,19]. This study utilizes the average partial variance of relative price changes for 21 commodities between adjacent provinces as a proxy variable for market segmentation.

$$MS = \frac{1}{21} \sum_{i=1}^{21} \text{Partial Variance} \Delta P_i \quad (5)$$

where ΔP_i is the relative price change of the i -th commodity between adjacent provinces and $\text{Partial Variance} \Delta P_i$ is the partial variance of this price change.

- (3) Industrial agglomeration denotes the phenomenon whereby enterprises, institutions, and related services and infrastructure of the same or related industries are highly concentrated in a specific region, forming industrial clusters with substantial competitiveness and influence. This paper employs the ratio of industrial added value to total industrial added value of each province relative to the GDP to total GDP of each province as a measure of industrial agglomeration.

$$IA = \frac{\text{Industrial Added Value of Province}}{\text{Total Industrial Added Value}} / \frac{\text{GDP of Province}}{\text{Total GDP}} \quad (6)$$

- (4) Environmental regulation intensity (ERS) pertains to the government's intervention in economic activities to safeguard the environment from harm or to ameliorate degraded environmental conditions. This study gauges the intensity of environmental regulation by measuring the frequency of terms such as “environmental protection”, “ecology”, “green”, “low carbon”, “air”, and others.
- (5) The green credit level (GCT) is a financial policy instrument wherein financial institutions integrate environmental factors into the loan decision-making process during credit activities, providing credit support to environmentally friendly enterprises and projects while restricting credit to those with poor environmental performance. This paper defines the green credit level as 1 minus the ratio of interest expenditure of six high-energy-consuming industries to the total interest expenditure of industrial industries.

$$GCT = 1 - \frac{\text{Interest Expenditure of High Energy – Consuming Industries}}{\text{Total Interest Expenditure of Industrial Industries}} \quad (7)$$

- (6) The level of industrialization (IL) is operationalized as the ratio of industrial added value to GDP.

$$L = \frac{\text{Industrial Added Value}}{\text{GDP}} \quad (8)$$

2.3.4. Control Variables

Referring to the research of Hong Q., Cui L., and Hong P. [33]; Sheng J., Gao X., and Sun Y. [34]; and other scholars [35,36], the control variables selected in this paper are as follows:

- (1) Economic development level (RGDP)—Economic development promotes the efficient management of resources and the investment of ecological funds, which improves the ecological benefits and realizes the balanced development of economy and ecology. Therefore, this paper chooses per capita regional GDP to measure the level of economic development.
- (2) Human capital (HC)—High-quality human capital can enhance the R&D and application ability of low-carbon technology in enterprises and help ecological development.

Therefore, this paper chooses the number of students in ordinary colleges and universities to measure human capital.

- (3) Resident income level (RIL)—A higher resident income usually means stronger environmental awareness and consumption ability, which can promote the demand for green products and services. Therefore, this paper chooses the per capita disposable income level of urban residents to measure the income level of residents.
- (4) Government intervention (GOI)—As a provider of policy making and public goods, appropriate government intervention can maintain market order, regulate the productive behavior of the economy, and reduce the damage of industry to the environment. Therefore, this paper chooses the ratio of government expenditure to regional GDP to reflect the degree of government intervention.
- (5) The level of foreign direct investment (FDI)—On the one hand, according to the “pollution paradise” hypothesis, foreign direct investment will bring high energy consumption and high pollution enterprises in developed countries, increasing China’s ecological pressure; on the other hand, according to the “pollution halo” hypothesis, foreign direct investment will introduce more advanced low-carbon environmental protection technology to buffer some ecological pressure. Based on this, this paper selects the ratio of foreign direct investment to regional GDP to represent the level of foreign direct investment.

The descriptive statistics of each variable are shown in Table 2.

Table 2. Descriptive statistics.

Variable	Definition	N	Mean	Min	Max
InEF	Per capita ecological footprint (hectares/person)	510	0.479	−0.82	1.91
DiD	The cross term of policy dummy variable and policy time node variable	510	0.11	0	1
RGDP	GDP per capita (CNY 10 thousand/person)	510	15.33	0.81	15.33
HC	The number of undergraduate students in ordinary colleges and universities (ten thousand)	510	47.35	1.99	129.98
GOI	The ratio of government expenditure to regional GDP	510	0.11	0.06	0.21
OP	The total import and export accounted for the proportion of regional GDP	510	3.061	0.076	17.1
RIL	Per capita disposable income level of urban residents (CNY)	510	2.62	0.8013	8.2429
CO ₂	Total CO ₂ emissions (ten thousand tons)	510	37,149.32	626.4	110,527.8
TI	The number of patent application authorization (pieces)	510	45,797.37	228	478,082
MS	The average value of partial variance of relative price changes of 21 commodity categories in adjacent provinces	510	0.00043	0.00009	0.00316
IA	The ratio of industrial added value/total industrial added value of each province to the total GDP/total GDP of each province	510	0.94244	0.31367	1.38825

2.4. Data Sources and Processing

Due to the incomplete statistical data available for Tibet, as well as the challenges in acquiring relevant data for Taiwan, Hong Kong, and Macao, this paper excludes these four regions and focuses on 30 provinces and cities in China as research samples for the period of 2005–2021 to conduct a series of empirical analyses. The energy consumption data for each land type were sourced from the *Fishery Statistical Yearbook*, *Natural Resources Bulletin*, and *China Energy Statistical Yearbook*. The data regarding the level of economic development, human capital, and residents’ income level were obtained from the *China Statistical Yearbook*. The data for other control variables and core mechanism variables were derived from the Mark database. At the same time, in order to eliminate the disturbance of extreme values to the regression results, this paper winsorized the panel data at the 1% level, and the missing data were filled in using linear interpolation.

3. Results and Analysis

3.1. Spatio-Temporal Evolution Characteristics of Ecological Pressure in China

In order to explore how CETP uses government constraints and market-oriented means to resolve the contradiction between human production/life and ecological environment development to achieve carbon emission reduction targets, thus promoting ecological sustainable development, this paper gives the change situation of ecological pressure from two dimensions of time and space and summarizes the characteristics of China's overall and regional ecological pressure, as shown in Figures 2 and 3.

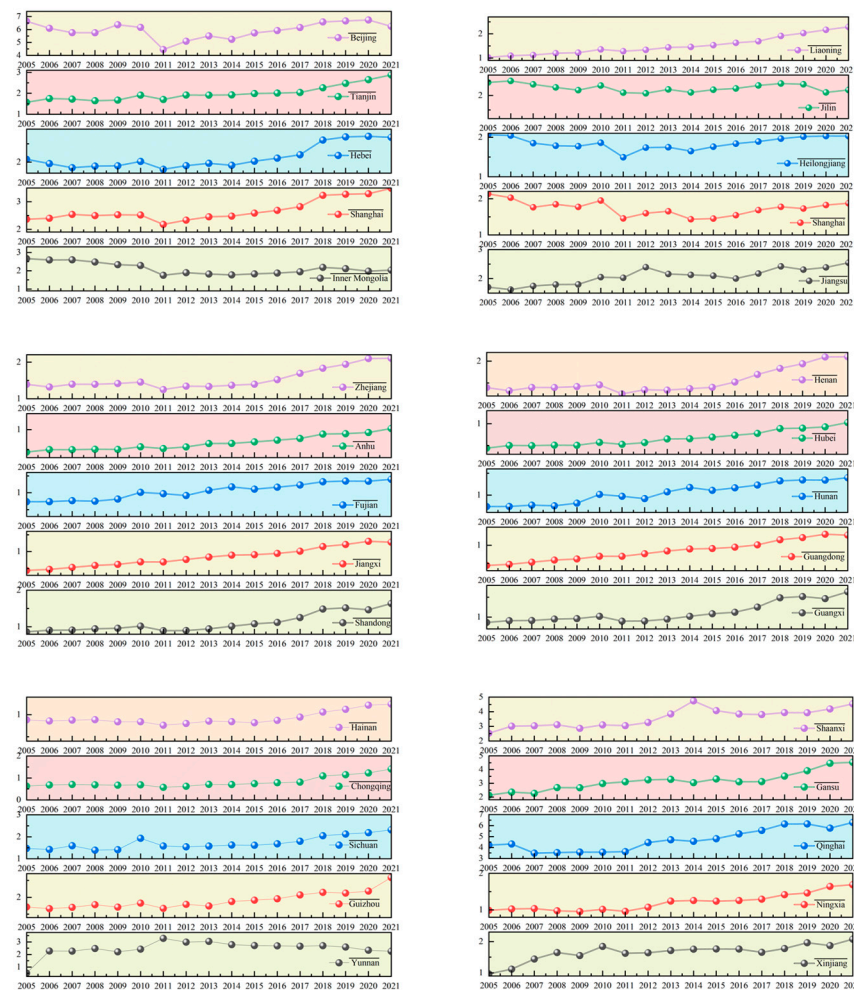


Figure 2. Ecological footprint per capita of all provinces in China, 2005–2021.

3.1.1. The Temporal Evolution Characteristics of Ecological Pressure in China

In terms of time, the change trend in ecological pressure was graphically explored by using histograms, and the temporal evolution characteristics of ecological pressure level in each province were further analyzed. From 2005 to 2021, the increase in ecological pressure in Liaoning, Jiangsu, Jiangxi, and Chongqing was particularly significant. Among them, the fastest growing region, Ningxia Province, increased from 2.99 hectares/person in 2005 to 4.53 hectares/person in 2021. During this period, it increased by about 1.52 times, with an average annual growth rate of about 15%. In addition, the ecological pressure of Beijing, Hebei, Inner Mongolia, Jilin, and other provinces decreased first and then increased, and the increase (60%) was much higher than the decrease (10%). In summary, the ecological burden of China's provinces has generally increased, and the pressure in some areas has increased significantly, showing a rising growth trend.

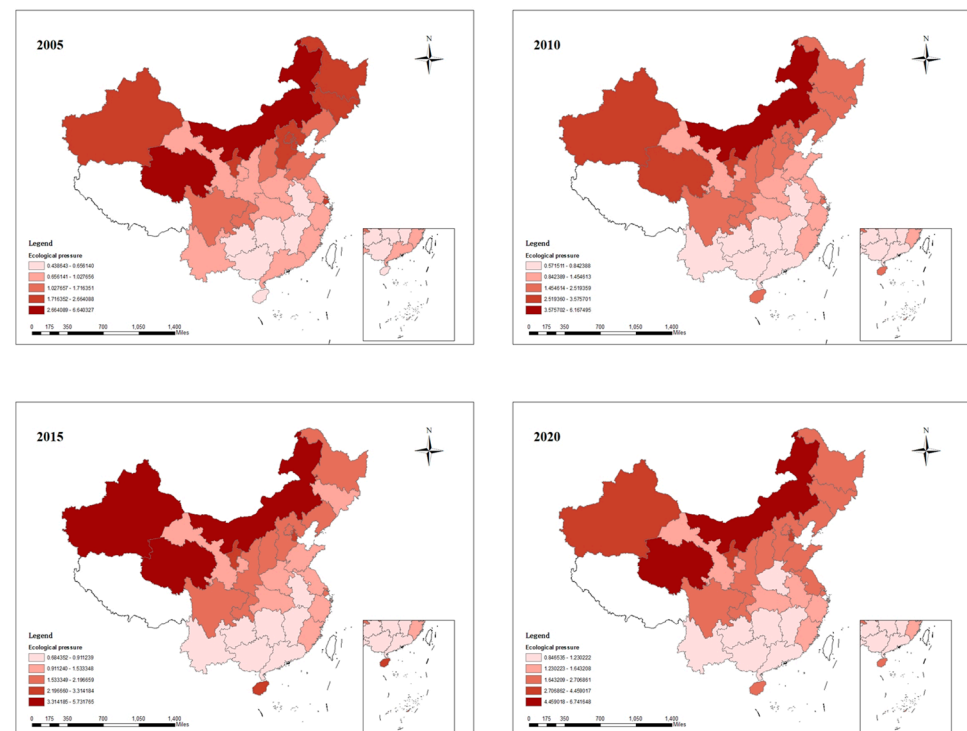


Figure 3. Spatio-temporal evolution trend in ecological pressure in China, 2005–2021.

3.1.2. Spatial Evolution Characteristics of Ecological Pressure in China

With the help of Arcgis 10.8, the ecological pressure level was divided into five grades using the natural discontinuity point classification method, and the spatial distribution of the four periods of 2005, 2010, 2015, and 2020 was visualized more intuitively, as shown in Figure 3. The ecological pressure was bounded by the “Hu Huanyong line”. The ecological pressure in Sichuan, Shaanxi, Shanxi, Hebei, and other regions east of the line was about 1.8 hectares/person, and the ecological pressure in Yunnan, Guizhou, Hunan, Jiangxi, and other southern regions was about 0.7 hectares/person. The ecological pressure in Inner Mongolia, Qinghai, Ningxia, Xinjiang, and other northern regions to the west of the line fluctuated at the level of 4.5 hectares/person, which is 2.5 times that of the central region and 6.4 times that of the southern region. At the same time, the ecological pressure levels in the adjacent areas of the Yangtze River Economic Belt were generally low, and the seven provinces with the lowest ecological pressure levels were all gathered here. In summary, the ecological environment in northwest China faced greater pressure, while it was at a lower level in the southeast, and the ecological pressure level of each province was significantly different.

3.2. Baseline Regression

According to Model (1), Column (1) of Table 3 shows that when the control variables are not added, only the time and provincial fixed effects are considered. The policy implementation significantly reduced the ecological pressure in the treatment group. Specifically, the DiD coefficient of -0.181 indicates that the ecological pressure index in the treatment group decreased by an average of 0.181 units following the policy implementation. Column (2) indicates that the fixed effect and control variables, such as per capita GDP and human capital, are included in the model. The carbon trading coefficient was -0.169 , which is still significantly negative at the statistical level of 1%, and the value was almost unchanged. The government has curbed the rent-seeking behavior of environmental resources through laws and regulations, ensuring the fairness and efficiency of ecological environment gov-

ernance. At the same time, the market mechanism has provided economic incentives for emission reductions, prompting enterprises to seek innovative technologies and optimal allocation of resources and guiding capital to flow to green energy projects. Hypothesis 1 of the article is expected to be established.

Table 3. Baseline regression.

	(1)	(2)
Variables	lnEF	lnEF
DiD	−0.181 *** (0.0614)	−0.169 *** (0.0457)
RGDP		0.0492 * (0.0254)
HC		0.00147 (0.00224)
RIL		−0.113 (0.0906)
GOI		1.119 (0.759)
OP		0.0141 (0.0113)
Constant	0.498 *** (0.00650)	0.342 (0.293)
City	Yes	Yes
Year	Yes	Yes
Observations	510	510
R-squared	0.955	0.956

Note: *, **, *** are expressed as significant at the levels of 10%, 5%, and 1%, respectively. The values in parentheses are standard errors, the same below.

3.3. Robustness Test

3.3.1. Parallel Trends Test

In this paper, the difference-in-differences method was used to test the impact of CETP on ecological pressure. Therefore, there should be no significant differences in the trend between the experimental group and the control group before the policy intervention so as to ensure the effectiveness and accuracy of causal inference. In order to test whether the study meets the parallel trend, the model was set as follows:

$$\ln EF_{it} = \delta_0 + \sum_{-7}^7 \beta_t (\text{treat}_i \times T_t) + \beta_X X_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (9)$$

Among them, the explanatory variable $\sum_{-7}^7 \beta_i (\text{treat}_i \times T_t)$ represents whether region i is a pilot area of CETP and the interaction term of 7 years before and after the implementation of the policy, and the remaining variables have the same meaning as the benchmark regression model.

The parallel trend test results are shown in Figure 4. Before the implementation of the policy, there was no significant trend difference between the provinces with and without carbon pilot projects, and the significant effect at the statistical level could not be achieved. After the implementation of the policy, the ecological pressure of the carbon pilot provinces was greatly reduced, and the parallel trend test was met.

3.3.2. Other Robustness Tests

- (1) Placebo test—In order to test the stability of the benchmark regression results, this paper generated 500 groups of virtual carbon pilot provinces and conducted regression analyses. As shown in Figure 5, the results were no longer significant, that is, the

implementation of the virtual sample combination policy had no inhibitory effect on ecological pressure, and the benchmark regression was robust.

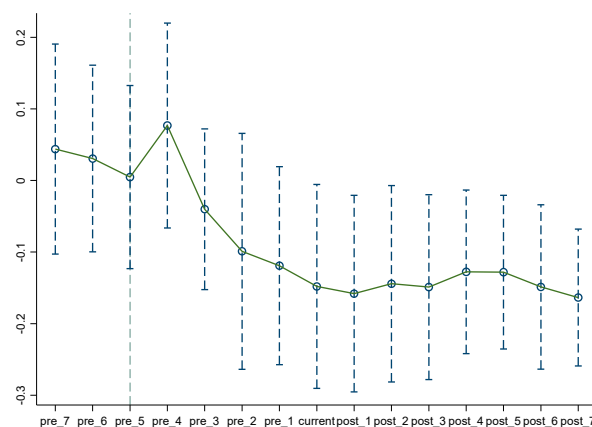


Figure 4. Parallel trend test.

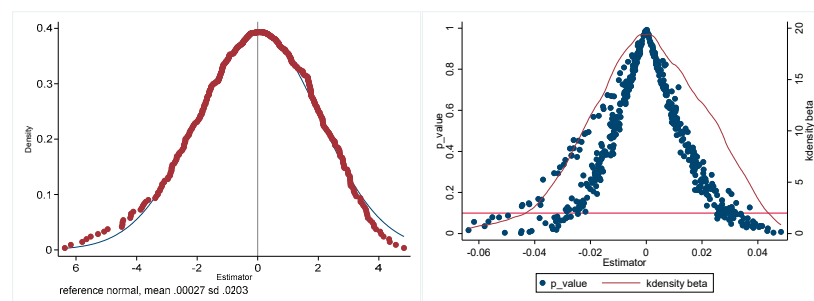


Figure 5. Placebo test.

- (2) Lagged one-stage test—Considering the time lag of the policy, it may be difficult to achieve the expected effect when the CETP is initially implemented. Therefore, the policy variable was lagged one period to replace the original policy variable, and the regression was carried out again. As shown in Table 4, the results were still significant, and the benchmark regression results were robust [36].

Table 4. Lagged one-stage test.

		(1)
Variables		lnEF
L.DiD		−0.126 ** (0.0464)
RGDP		0.0440 * (0.0256)
HC		0.00210 (0.00244)
RIL		−0.0985 (0.0946)
GOI		0.446 (0.777)
OP		0.0140 (0.0104)
Constant		0.375 (0.287)
City		Yes
Year		Yes
Observations		480
R-squared		0.970

- (3) Replacement of the core explanatory variables—The index system was constructed by using chemical fertilizer application amounts, pesticide application amounts, green coverage rates of built-up areas, and domestic waste clearance volumes, and the ecological pressure was calculated by the entropy method to replace the core explanatory variables (Table 5). The CETP significantly reduced the ecological pressure, which was consistent with the benchmark regression results [37].

Table 5. Replacement of the core explanatory variables.

Variables	(1)
	Ecological Pressure Index
DiD	−0.0538 *** (0.0139)
RGDP	−0.00273 (0.00949)
HC	−0.000335 (0.000408)
RIL	0.0180 (0.0235)
GOI	0.0858 (0.207)
OP	−0.305 (0.264)
Constant	0.441 *** (0.0376)
City	Yes
Year	Yes
Observations	510
R-squared	0.926

- (4) Change in the sample time range—China’s environmental protection supervision started with Hebei Province in January 2016 and fully covered 31 provinces in 2017. By 2018, the implementation of supervision was reviewed. Due to its rigid constraints, public participation, continuous tracking, and other characteristics, it was called the “green storm” of China’s environmental governance by the media [38]. In order to eliminate the impact of the policy in the same period, this paper excluded the data after 2015 for testing, and the results were still significantly negative (Table 6).

3.4. Mechanism Test

3.4.1. Policy Constraints: Carbon Emission Reduction Effect

The regression results presented in Table 7 indicate that the core explanatory variables exhibited a significantly negative relationship at the 1% significance level. This finding substantiates the effectiveness of carbon trading policies as an environmental regulatory instrument. By establishing carbon emission caps for enterprises and incentivizing investment in clean technologies and improvements in resource and energy efficiency, these policies have successfully curtailed CO₂ emissions. The implementation of carbon trading policies not only encourages enterprises to refine their production processes and diminish carbon emissions but also stimulates the development and innovation of associated environmental protection technologies. Consequently, this fosters a broader green transformation of the economic structure.

Table 6. Change in the sample time range.

Variables	(1)
	lnEF
DiD	−0.160 *** (0.0407)
RGDP	0.0768 (0.0568)
HC	−0.000375 (0.00244)
RIL	−0.262 * (0.147)
GOI	1.664 (2.045)
OP	0.0505 (2.325)
Constant	0.493 (0.339)
City	Yes
Year	Yes
Observations	330
R-squared	0.957

Table 7. CETP constraint mechanism.

Variables	(1)
	CO ₂
DiD	−0.651 *** (0.138)
RGDP	0.124 (0.0781)
HC	−0.0202 *** (0.00495)
RIL	−0.784 *** (0.231)
GOI	3.873 * (2.056)
OP	−1.157 (2.297)
Constant	5.852 *** (0.567)
City	Yes
Year	Yes
Observations	510
R-squared	0.991

Drawing from the theory of carbon sequestration, ecosystems possess the capability to fix carbon by converting CO₂ into organic matter. Both terrestrial and marine ecosystems serve as carbon sinks, absorbing CO₂ from the atmosphere. These ecosystem carbon sinks are instrumental in preserving the Earth's carbon balance. For instance, forests absorb substantial amounts of CO₂ through photosynthesis, transforming it into organic matter and storing it within plant biomass, thereby reducing atmospheric CO₂ concentrations. However, if anthropogenic carbon emissions from unscientific production activities significantly exceed the capacity of ecosystem carbon sinks, it disrupts the healthy and balanced development of ecosystems. Excessive emissions lead to a continuous rise in atmospheric CO₂ levels, precipitating a cascade of ecological and environmental issues, including global warming. Conversely, effective control of carbon emissions enables ecosystem carbon sinks to function optimally, absorbing and storing greater quantities of CO₂ and maintaining

ecosystem stability and sustainability. This not only helps to decelerate the pace and extent of climate change but also creates favorable conditions for biodiversity conservation and ecosystem restoration. Thus, the reduction in total carbon emissions achieved through the implementation of carbon trading policies contributes to keeping carbon emissions within the acceptable range of ecosystems, alleviating ecological pressure, and thereby validating Hypothesis 2.

3.4.2. Market Regulation Effect

In this study, the average variance of relative price changes across 21 commodity categories between neighboring provinces was employed as a market-specific metric to assess the influence of market segmentation on the efficacy of carbon trading policies. As illustrated in Table 8, the coefficients for the carbon trading policy and its interaction term were significantly negative (coefficients were -0.137 and 0.0927 , with p -values less than 0.01 and 0.05 , respectively), indicating that market segmentation attenuates the suppressive impact of carbon trading policies on ecological pressure.

Table 8. Market regulation mechanism.

	(1)
Variables	lnEF
DiD	-0.137^{***} (0.0461)
DiDMS	-0.0927^{**} (0.0410)
MS	0.0157 (0.0308)
RGDP	0.0491 [*] (0.0251)
HC	0.00144 (0.00225)
RIL	-0.113 (0.0902)
GOI	1.138 (0.758)
OP	0.0143 (0.0115)
Constant	0.333 (0.292)
City	Yes
Year	Yes
Observations	510
R-squared	0.956

Firstly, market segmentation results in diminished information transparency, impeding enterprises from promptly acquiring data on carbon emission quota prices, trading regulations, and advancements in related technologies, thereby affecting their decision making and actions within the carbon market. For instance, companies may be unable to accurately evaluate the benefits and risks associated with investing in clean technologies, leading to inadequate investment and innovation in carbon emission reductions.

Secondly, market segmentation obstructs the free movement of resources, preventing effective trading and allocation of carbon emission quotas across different regions. This hindrance to resource flow reduces the vibrancy of the carbon market, limiting competition and collaboration among enterprises. Firms in some regions may be compelled to curtail production or investment due to insufficient carbon emission quotas, while those in other regions might fail to fully leverage their emission reduction potential due to an excess of

quotas. This inefficient resource allocation not only diminishes the overall carbon emission reduction effect but may also result in unfair competition among enterprises.

Lastly, market segmentation increases entry barriers for enterprises, making it more challenging for them to learn from and imitate one another. Under carbon trading policies, enterprises need to continuously learn and adopt advanced carbon emission reduction technologies and management practices to enhance their competitiveness and adaptability to market changes. However, market segmentation leads to restricted communication and collaboration between enterprises, hindering their timely acquisition and absorption of these advanced technologies and experiences. Enterprises cannot share their innovative achievements and practical experience in carbon emission reduction with others, thereby affecting the technological progress and innovation capacity of the entire industry. Consequently, market segmentation diminishes the mitigation effect of carbon emissions trading pilot policies on ecological pressure, thereby validating Hypothesis 3.

3.4.3. Industrial Response: Industrial Innovation Effect and Industrial Agglomeration Effect

In this paper, the quantity of patent application authorizations was incorporated as an indicator of technological innovation level to examine its influence on the industry's response to carbon trading policies. The regression results are presented in column (1) of Table 9. The coefficients for the carbon trading policy and its interaction term with the technological level were significantly negative (coefficients were -0.586 and -0.539 , with p -values less than 0.1 and 0.01, respectively), indicating that advancements in technological level enhanced the suppressive effect of carbon trading policies on ecological pressure. This finding can be elucidated from two perspectives:

Table 9. Industry response mechanism.

	(1)	(2)
Variables	lnEF	lnEF
DiD	-0.0986^* (0.0490)	-0.519^{***} (0.151)
DiDTI2	-0.539^{***} (0.189)	
TI2	0.895^{***} (0.231)	
DiDIA		0.384^{**} (0.150)
IA		0.227 (0.159)
RGDP	0.0354^* (0.0203)	0.0292 (0.0245)
HC	-0.000940 (0.00241)	0.000363 (0.00200)
RIL	-0.143^{**} (0.0638)	-0.0403 (0.0790)
GOI	0.873 (0.782)	0.599 (0.795)
OP	0.0163 (0.0108)	0.0103 (0.0114)
Constant	0.572^{**} (0.278)	0.147 (0.266)
City	Yes	Yes
Year	Yes	Yes
Observations	510	510
R-squared	0.958	0.958

Firstly, technological progress facilitates the production of environmentally friendly products, thereby improving the interaction between humans and nature at the source. Technological innovation can encourage enterprises to adopt more eco-friendly raw materials and processes in their production activities, reducing the consumption of natural resources and environmental pollution. Specifically, firms can decrease energy consumption and carbon emissions during production by developing and implementing more efficient energy utilization technologies. Additionally, technological innovation can promote the development of a circular economy, alleviating ecosystem pressure by enhancing resource recycling rates and reducing waste generation and emissions.

Secondly, a high technological level can expedite the repair process of ecological damage and minimize ecological losses. Technological innovation not only enables enterprises to monitor and manage their carbon emissions more effectively but also provides more advanced ecological restoration technologies to accelerate the recovery of damaged ecosystems. Through remote sensing monitoring technologies and big data analysis, firms can more accurately grasp the distribution and changes in their carbon emissions, allowing them to formulate more targeted emission reduction measures. Moreover, advancements in ecological restoration technologies enable enterprises to more effectively repair ecosystems damaged by production activities, such as afforestation and wetland restoration, thereby improving the carbon sink capacity of ecosystems.

When discussing the impact of industrial agglomeration on the effectiveness of carbon trading policies, this paper employed the ratio of industrial added value to total industrial added value in each province relative to the ratio of GDP to total GDP in each province as the index of industrial agglomeration level. The regression results are displayed in column (2) of Table 7. The coefficient for the carbon trading policy was significantly negative, while the interaction term was significantly positive (coefficients were -0.519 and 0.384 , with p -values less than 0.01 and 0.05 , respectively), indicating that industrial agglomeration diminished the suppressive effect of carbon trading policies on ecological pressure. Industrial agglomeration leads to a large number of enterprises concentrating in a region for production activities, substantially increasing local pollution emissions and overwhelming the ecosystem's capacity to withstand this concentrated and intensive production form. Specifically, in areas with a high degree of industrial agglomeration, the discharge of pollutants such as wastewater, exhaust gases, and solid waste far exceeds local environmental capacity due to the large number of enterprises and the scale of production, resulting in a significant decline in the quality of the surrounding ecological environment. Furthermore, industrial agglomeration may also lead to a series of environmental issues, such as excessive resource consumption and ecological damage. Simultaneously, in industrial agglomeration areas, enterprises may overexploit and utilize local natural resources in pursuit of economic benefits, undermining the balance and sustainable development of the ecosystem. These issues weaken the mitigation effect of carbon trading policies on ecological pressure, significantly reducing the policy's effectiveness in industrial agglomeration areas.

In summary, improvements in technological level can effectively enhance the suppressive effect of carbon trading policies on ecological pressure, while industrial agglomeration mitigates this policy effect to a certain extent. Hypothesis 4 is thereby validated.

3.5. Heterogeneity Test

3.5.1. Environmental Regulation Intensity

The implementation of stringent environmental regulation entails more rigorous carbon emission limitations, thereby incentivizing enterprises to adopt proactive emission reduction strategies and consequently diminishing ecological pressure. Specifically, environmental regulation constrains and steers corporate pollution emission behaviors through

the establishment of emission standards, the imposition of sewage charges, the enforcement of sewage permits, and other regulatory mechanisms. On the one hand, environmental regulation escalates the costs associated with pollution control for enterprises, compelling them to factor in environmental expenses alongside their pursuit of economic gains. This dynamic prompts enterprises to augment their investments in environmental protection, embrace cutting-edge pollution control technologies and equipment, enhance resource utilization efficiency, and curtail pollutant emissions [39,40]. For instance, stringent emission standards compel companies to refine their production processes, utilize low-sulfur fuels, and implement desulfurization and denitrification technologies, thereby mitigating the emissions of air pollutants such as sulfur dioxide and nitrogen oxides. On the other hand, environmental regulation bolsters societal environmental oversight of enterprises via information disclosure and public engagement, elevating their environmental responsibility consciousness and social image and encouraging a heightened focus on sustainable development [41,42].

This paper calculated the median of word frequency of environmental protection, ecology, green, low carbon, air, and other words and set results higher than the median as areas with high environmental regulation intensity and lower than the median as areas with low environmental regulation intensity [43,44]. The regression results of columns (1) and (2) in Table 10 show that compared with regions with low environmental regulation intensity, regions with high environmental regulation intensity can strengthen the direct binding capacity of CETP and reduce ecological pressure.

Table 10. Heterogeneity test.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Areas with High Intensity of Environmental Regulation	Areas with Low Intensity of Environmental Regulation	Areas with High Green Credit Level	Areas with Low Green Credit Level	Areas with High Level of Industrialization	Areas with Low Level of Industrialization
DiD	−0.196 *** (0.0372)	−0.0776 (0.0997)	−0.194 *** (0.0482)	−0.00914 (0.0688)	−0.163 *** (0.0228)	−0.0116 (0.0617)
RGDP	0.0646 ** (0.0256)	0.0271 (0.0483)	0.0778 ** (0.0299)	−0.0190 (0.0329)	0.0645 *** (0.0160)	−0.0378 (0.0570)
HC	−0.00122 (0.00214)	0.00508 (0.00299)	0.00124 (0.00394)	−0.704 (22.54)	−0.00201 (0.00156)	0.00391 (0.00308)
RIL	−0.299 *** (0.0975)	0.0142 (0.142)	−0.134 (0.0964)	−0.227 (0.157)	−0.0586 (0.0514)	0.0197 (0.190)
GOI	−1.118 (1.249)	1.556 (1.065)	2.566 (1.679)	0.0298 (1.311)	2.562 ** (1.143)	1.747 (1.027)
OP	−0.0123 (0.0104)	0.0396 (0.0380)	0.0213 (0.0135)	−0.00526 (0.0164)	0.00665 (0.00556)	0.0276 (0.0210)
Constant	1.109 *** (0.292)	−0.157 (0.393)	−0.0687 (0.486)	1.213 ** (0.470)	0.103 (0.214)	0.290 (0.433)
City	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	260	250	270	240	276	234
R-squared	0.981	0.938	0.907	0.984	0.978	0.953

3.5.2. Green Credit Level

Green credits, as the cornerstone of the green finance framework, play an indispensable role in assessing potential pollution risks and establishing pollution prevention and control mechanisms within credit activities. Financial institutions, when extending loans, determine the provision of credits and the interest rates and amounts based on a company's environmental performance and the ecological attributes of the project in question [45,46]. For pollution-intensive projects, green credit policies restrict access to loans or increase the cost of borrowing, thereby curbing corporate investment in polluting activities. For instance, in industries with high energy consumption and pollution levels, such as steel and

chemical manufacturing, banks are more stringent in loan approvals, requiring companies to provide detailed environmental impact assessments and pollution control plans. If a company's environmental measures are inadequate, it may face the risk of loan application denial or higher interest rates. Conversely, for green and low-carbon investments, such as projects in renewable energy, energy conservation and emission reduction, and green transportation, green credit policies offer priority support and preferential interest rates, encouraging increased investment in these areas. In this manner, green credits channel funds towards the environmental sector, aiding in industrial technology upgrades and fostering corporate green transformation and pollution control.

This article set the green credit level = $1 - (\text{the interest expenditure of the six high-energy-consuming industries} / \text{the total interest expenditure of the industrial industry})$ and measured the median of the green credit level. Results higher than the median were set to the area with a high green credit level, and results lower than the median were set to the area with a low green credit level [47]. The regression results of columns (3) and (4) in Table 8 show that the policy effect in regions with higher green credit levels was more significant than in regions with lower green credit levels.

3.5.3. Level of Industrialization

There are significant differences in the industrial structures of regions with varying levels of industrialization. On the one hand, in areas with higher degrees of industrialization, the industrial structure is relatively diversified. In addition to traditional high-energy-consuming industries, there is a greater presence of high-tech industries and service sectors. These industries are more sensitive to carbon emissions, and carbon trading policies can effectively motivate enterprises to engage in green innovation and transformation and upgrading. For instance, high-tech industries such as electronic information and biopharmaceuticals can significantly reduce carbon emissions by developing low-carbon products and improving production processes. In contrast, in regions with lower levels of industrialization, the industrial structure is relatively monolithic, with a larger proportion of high-energy-consuming and high-emission industries. The implementation of carbon trading policies is more challenging, and the pathways for enterprise transformation are relatively limited [48].

On the other hand, enterprises in regions with high industrialization levels generally possess strong market competitiveness and adaptability. Faced with the cost pressures brought about by carbon trading policies, these enterprises can quickly adjust their business strategies, optimize resource allocation, and enhance production efficiency, thereby maintaining a competitive edge in the market. However, in regions with lower levels of industrialization, enterprises are smaller in scale and weaker in financial strength, and their adaptability to market changes is relatively poor. The implementation of carbon trading policies may impose significant operational pressures on these enterprises, affecting their normal production and business activities.

In this paper, the level of industrialization was defined as the ratio of industrial added value to regional gross domestic product (GDP). The median value of the industrialization level was calculated, with regions above the median classified as having a high level of industrialization and those below the median classified as having a low level of industrialization. The regression results in columns (5) and (6) of Table 8 indicate that the policy effects in regions with a high level of industrialization were more pronounced compared to those with a low level of industrialization.

4. Economic Benefit

Ecological total factor productivity not only covers traditional production factors such as capital and labor but also includes environmental factors such as energy consumption and pollutant emissions. At the same time, its output indicators include both pollutant indicators and GDP indicators. Therefore, this paper selected ecological total factor productivity (Eco-TFP) as a measure to verify whether the carbon trading policy can take into account both ecological and economic benefits. The indicator system of ecological total factor productivity and the calculation results are shown in Tables 11 and 12.

Table 11. Indicator system.

Category	Indicator	Definition
Input indicator	Capital input	Year-end fixed asset value of large enterprises
	Labor input	Number of unemployed individuals in production departments
	Ecological input	Total energy consumption of production departments
Output indicator	Desired output	GDP
	Undesired output	Solid waste emissions
		Industrial sulfur dioxide emissions Industrial wastewater discharge

Table 12. Economic benefit.

	(1)
Variables	lnEF
DiD	0.0423 * (0.0235)
HC	0.529 (0.491)
RIL	0.0465 ** (0.0222)
GOI	−1.113 ** (0.427)
OP	−0.615 (0.462)
Constant	1.041 *** (0.0745)
City	Yes
Year	Yes
Observations	510
R-squared	0.461

In constructing the indicator system for ecological total factor productivity (Eco-TFP), GDP was already taken into account. Therefore, to prevent multicollinearity issues in the regression analysis, per capita GDP was omitted as a control variable. According to the regression results presented in Table 12, the carbon trading policy had a significantly positive impact on the enhancement of Eco-TFP, with a coefficient of 0.0423 and a statistical significance level of $p < 0.1$. This finding indicates that while effectively reducing ecological pressure, the carbon trading policy does not adversely affect economic development. Instead, it contributes to sustaining economic growth, achieving a win–win objective of ecological protection and economic prosperity.

5. Conclusions

Based on the reality of ecological civilization construction in the new era, the implementation of CETP has had a positive impact on the solution to the “source” problem. However, there is still a lack of in-depth analysis and exploration on whether this policy

can further reduce the overall impact of human beings on the ecological environment to cope with the “sink” problem. Based on this, this paper examines the impact of CETP on ecological pressure by measuring the ecological footprint of 30 provinces in China and using the difference-in-differences method. This paper finds that, firstly, CETP can effectively reduce the ecological pressure brought by human activities. Additionally, CO₂ emissions will affect the mitigation effect of ecological pressure. When the carbon emissions generated by human’s unscientific production activities are much higher than the carbon sink level of the ecosystem, it will interfere with the healthy and balanced development of the ecosystem and increase the ecological pressure. Thirdly, unified market regulation is more conducive to technology imitation and resource flow, thus enhancing the effect of CETP. Fourthly, when the technical level promotes the production of green products and shortens the process of ecological restoration, CETP can effectively reduce the ecological pressure, while industrial agglomeration will lead to excessive pollution, which is difficult for the government to control accurately, and the inhibition effect of carbon trading on ecological pressure will be weakened. Finally, a high level of green credits will guide the flow of funds to the field of environmental protection, provide support for technological innovation to help enterprises’ green transformation and environmental governance, and further enhance the effectiveness of CETP. In regions with a high level of industrialization, enterprises generally possess strong market competitiveness and adaptability.

6. Policy Recommendations

The conclusion of this paper shows that CETP helps to promote the sustainable development of the ecological environment from the three dimensions of government level, industry level, and market level. Based on this, the following policy implications are proposed:

Improve the government’s ability to coordinate supervision—We must break the traditional mode of “fighting each other” between regulatory authorities and, vertically, unblock the communication and dialogue mechanisms between the central, local, grass-roots organizations and industrial departments. In the horizontal direction, we should ensure the liquidity and cross-regionality of supervision to improve the cross-sectoral supervision ability between departments, improve the supply efficiency of policy tools, and improve the effect of CETP to help solve the “sink” problem.

Promote the integration and unification of regional carbon markets—We must guide local governments to abandon the “land-keeping” thinking and pursuit of short-term interests, break down local protection barriers, and promote fair competition and optimal allocation of resources among regions. At the same time, we should strengthen communication and cooperation between regions, promoting information sharing in order to achieve mutual benefit and a win–win situation. In addition, we should improve the level of marketization and build a unified national market to stimulate market vitality and innovation capabilities, help industry improve its pollution waste treatment capacity and thus reduce environmental damage.

Encourage the autonomy of innovation-driven enterprises—To guide enterprises to invest in R&D on environmental protection technology and sustainable products, the government or industry associations should set up special funds to support innovation projects through the establishment of cooperation networks, promoting the sharing of resources and technology among enterprises, and realizing the collaborative innovation of enterprises across industries. Secondly, enterprises should be encouraged to follow and implement green standards, introduce intelligent management systems to optimize production processes, and improve production efficiency and resource utilization efficiency.

This will ensure that enterprises actively fulfill their social responsibilities while achieving economic benefits so as to contribute to ecologically sustainable development.

Tailor measures to local conditions and maximize policy benefits—For regions with a high intensity of environmental regulation, it is imperative to further refine and enhance carbon trading policies, improving their operability and pertinence. This entails encouraging enterprises to augment their investments in energy conservation, emission reductions, and green technologies, thereby facilitating the transition of industries towards greener and low-carbon pathways. Conversely, in regions characterized by low environmental regulatory intensity, the government must intensify environmental oversight. This involves formulating and implementing more stringent environmental regulations and standards, thereby increasing the costs associated with non-compliance and compelling enterprises to adopt emission reduction measures. In regions with high levels of green credit, efforts should be made to further expand their coverage, enhancing the precision and effectiveness of these policies. For areas with low levels of green credit, the government should bolster support for green credit initiatives. This can be achieved by reducing the risks and costs associated with financial institutions' green credit operations through measures such as financial discounts and risk compensation and by establishing a robust green credit risk assessment and management system.

Expand policy effects—Firstly, it is essential to improve the carbon trading market mechanism, broadening its coverage and gradually incorporating additional industries and regions into the carbon trading system. This includes sectors such as building materials, transportation, and finance, which will promote the upgrading and structural adjustment of low-carbon industries. Secondly, increasing incentives for enterprises is crucial. This can be accomplished through tax incentives and financial subsidies, which will reduce the costs for enterprises to participate in carbon trading and enhance their enthusiasm. Concurrently, strengthening the supporting framework for policies is vital. This involves improving relevant laws, regulations, and supervisory systems to ensure the standardized operation of the carbon trading market, providing a solid institutional foundation for the implementation of policies.

Author Contributions: Software, D.M.; Formal analysis, Y.W. (Yu Wang); Writing—original draft, Y.W. (Yu Wang) and D.M.; Writing—review & editing, Y.W. (Yu Wang), D.M., L.L. and Y.W. (Ying Wang); Visualization, D.M.; Supervision, Y.W. (Yu Wang). All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Program of National Natural Science Foundation of China (72163023); Natural Science Foundation of Inner Mongolia Autonomous Region of China (2023J005); The Youth Science and Technology Talent Project of Inner Mongolia Autonomous Region (NJYT23121).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy and ethical restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

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