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# Market-based environmental regulation and labor demand — An empirical study based on carbon emissions trading pilot policies

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## Abstract

The carbon emission trading system is an effective policy tool to realise carbon emission reduction. However, environmental regulation will inevitably affect economic and social operation, how to realize the coordination between promoting environmental protection and stabilising employment is a question that needs to be answered urgently. Based on the micro data of listed companies and the macro data at the city level from 2010 to 2021, this paper uses multi-period DID to study the impact of the carbon emissions trading system on labor demand and its mechanism. It is found that the carbon emission trading system reduces the labor demand of enterprises but increases the employment of cities, and the overall employment effect is positive. The mechanism test shows that the carbon emission allowance trading system causes the reduction of enterprise labor demand mainly through the factor substitution effect, skills, and there is a different effect of the policy effect. Further research shows that the carbon emission right trading system make the flow of labor from polluting industries to non-polluting industries and from non-pilot areas to pilot areas. Therefore, the policy effect is inconsistent between micro and macro effects. The findings of this paper provide a useful reference for improving the carbon trading system and safeguarding employment

## Keywords

Carbon emission trading; Labor demand; Labor reallocation; DID

## 1. Introduction

Global climate issues are one of the most complex environmental problems facing humankind(Wei et al., 2018). The report “State of the Global Climate in 2023” released by the World Meteorological Organization (WMO) states that the average global near-surface temperature in 2023 is 1.45°C higher than the average level from 1850 to 1900, greenhouse gas concentrations represented by carbon dioxide continue to rise, and extreme weather events around the world have caused economic losses of hundreds of billions of dollars. As the largest developing country, China's long-term extensive development model has caused serious environmental pollution problems, threatening sustainable economic growth (Huang et al., 2022). In order to achieve a shift in economic growth momentum and solve ecological and environmental problems, the Chinese government has adopted a series of environmental regulatory measures, which have achieved remarkable results. Since the 18th National Congress of the Communist Party of China, the Chinese government has introduced more than 120 institutional measures on the ecological environment in areas such as environmental governance, pollution prevention and control, energy conservation and emission reduction. The Party's 14th Five-Year Plan also clearly states: “We will intensify the fight against pollution, establish and improve the environmental governance system, promote pollution and carbon reduction in a coordinated manner, and continuously improve air and water quality.”

## 2. Theoretical analysis

The carbon emissions trading mechanism is a typical practice that uses the Coase theorem to solve the tragedy of the commons(Hu et al., 2023). The total amount of carbon emissions that the world can bear is limited, and carbon emission rights can be regarded as a commodity with special attributes that are allowed to be traded in the market. The carbon market sets the total emission target and allocates carbon emission quotas to enterprises using the historical method or industry benchmark method. Enterprises with high pollution and emissions need to purchase the corresponding carbon quotas on the carbon market. The negative externalities caused by their production activities are internalized through the price mechanism, thereby limiting the total carbon emissions of the enterprise. Enterprises with low emissions and low energy consumption can sell the surplus carbon quotas and receive a certain compensation.

### 2.1. Scale effect

According to the neoclassical school of thought's “cost follows” hypothesis, a carbon emissions trading system that incorporates the environmental factor as a production factor into the production process of enterprises will increase the marginal production cost of enterprises and reduce the scale of production. First, if carbon emissions exceed the obtained carbon quota, enterprises face two options: purchasing carbon quotas in the carbon market and reducing the scale of production. Purchasing carbon quotas will increase the production cost of enterprises, and reducing the scale of production will directly lead to a decrease in labor demand. Second, in order to reduce their own carbon emissions, companies need to make additional environmentally friendly investments in various production processes to purchase equipment and introduce technology, which will increase marginal production costs and prompt them to reduce production scale and lower labor demand. The carbon emissions trading system have a negative impact on the labor demand of enterprises by increasing their production costs and reducing production scale.

### 2.2. Substitution effect

Enviromental regulation can be categorised into two types: technology substitution and factor substitution. When facing environmental regulation, enterprises can primarily reduce pollution through two approaches: end-of-pipe and front-end. End-of-pipe involves installing pollution control equipment at the end of production to reduce emissions. The installation and maintenance of such equipment, as well as the testing phase, require greater labor input, resulting in a 'complementary effect' between environmental management and labor demand(Liu et al., 2021). Front-end reduction aims to control pollution at the source by improving production processes and introducing green technologies to reduce emissions from the source. New technologies and processes require higher skills from employees. Individuals with higher skills have the capacity to quickly learn and adapt to complex tasks. Consequently, when labor demand declines, high-skilled labor can substitute for low-skilled labor (Zheng et al., 2022).

### 2.3. Innovation compensation effect

According to Porter's hypothesis(Porter, 1995), the cost pressure under total carbon emission control will drive enterprises to optimize resource allocation or improve technology and production processes, thereby increasing total factor productivity. The improvement in production efficiency not only reduces the marginal production cost of the enterprise's products and gains a price advantage in the market, but also allows the enterprise to sell excess carbon allowances to gain partial income, offsetting some of the costs incurred by carbon emission reductions. During the process of improving production processes, enterprises will increase their demand for R&D positions by increasing R&D investment. On the other hand, the introduction of a large number of green and clean technologies and advanced processes has improved the production efficiency of enterprises, eliminating some of the labor force and causing employment losses.

## 3. Research design

### 3.1. Model construction and variable selection

As a policy evaluation tool that bases on “quasi-natural experiments” ,the difference-in-difference (DID) has been widely used in recent years in various fields(Chen et al., 2015). The carbon emissions trading pilot policy provides a “quasi-natural experiment” scenario for this paper to overcome endogeneity. The carbon emissions trading pilot policy was implemented in various regions in batches from 2013 to 2014, so the employment effect of the carbon emissions trading mechanism was estimated using a multi-period difference-in-difference method.

### 3.1.1. City

This paper first assesses the net effect of the carbon emissions trading system on regional employment at the city level. The specific model is set as follows:

$$\mathrm{CityLabor_{pt}} = \beta_0 + \beta_1 DID_{pt} + \beta_3 \mathrm{Z_{pt}} + \mu_\mathrm{p} + \eta_\mathrm{t} + \varepsilon_\mathrm{pt} \quad (1)$$

The dependent variable $\mathrm{Citylabor}_{pt}$ represents the number of employed people in city p in year t, expressed as the logarithm of the city's average number of employed people. The explanatory variable $\mathrm{DID}_{pt}$ is a dummy variable that reflects whether the city has implemented the pilot policy. If the city p implemented the policy in year t, the value is 1; otherwise, it is 0. $\mu_p$ indicates the city fixed effect; $\eta_t$ indicates the year fixed effect; and $\varepsilon_{pt}$ indicates other random disturbance terms that affect the employment level of the city. The coefficient β1 of the explanatory variable is the net effect of the carbon emissions trading policy on employment in the city, which is of interest in this paper. If β1 is significantly positive, it indicates that the carbon emissions trading policy helps to increase employment in the cities in the pilot area.

### 3.1.2. Enterprise

The impact of a carbon emissions trading on corporate employment is further assessed at the enterprise level, with the specific model settings as follows:

$$\mathrm{FirmLabor_{it}} = \alpha_0 + \alpha_1 \mathrm{policy_{it}} + \alpha_2 \mathrm{X_{it}} + \mu_\mathrm{i} + \eta_\mathrm{t} + \varepsilon_\mathrm{it} \quad (2)$$

The dependent variable $FirmLabor_{it}$ indicates the number of employees in enterprise i in year t, expressed as the logarithm of the total number of employees in the enterprise. The core explanatory variable $policy_{it}$ in this paper is a dummy variable that reflects whether the enterprise has implemented the pilot policy. If enterprise i is included in the list of pilot enterprises in year t, then the variable is 1; otherwise, it is 0. represents the fixed effect of the enterprise; εit represents the random disturbance term; and the remaining variables are the same as above. The coefficient of the explanatory variable is the coefficient of interest in this paper, which represents the net effect of the carbon emissions trading policy on employment in pilot enterprises. If it is significant and negative, it indicates that the implementation of the carbon emissions trading policy has a negative impact on employment in pilot enterprises.

### 3.2. Data source and explanation

Since the DID method requires that the explained variables of the control group and the treatment group after the policy are not disturbed by other policies, it is not easy to choose an excessively long sample interval(Sun et al., 2024). Secondly, it is ensured that each region has a window period of at least 3 years before the policy pilot, while avoiding the interference of the national carbon market implementation on policy evaluation. This paper selects 2010-2021 as the research period. At the city level, a total of 264 cities are selected as sample cities. The explained variables and other control variables at the city level are from the China City Statistical Yearbook.

# 4. Empirical results and analysis

## 4.1. Benchmark regression

Table 1 shows the impact of carbon trading policies on urban labor demand. Column (1) shows the average impact of carbon trading policies on urban labor demand without controlling for any other variables. After adding city-level control variables, the coefficient of the core explanatory variable in column (2) is significantly positive at the 10% level, indicating that the implementation of carbon trading policies has a significant positive impact on employment at the city level. Specifically, compared with non-pilot cities, the labor demand in pilot cities has increased by 11.4%.

**Table 1.** Impact of carbon emissions trading on urban labor demand

| Variable | CityLabor | CityLabor |
|---|---|---|
| | (1) | (2) |
| DID | 0.120** | 0.114* |
| | (0.055) | (0.059) |
| Observations | 3,128 | 3,128 |
| R2 | 0.964 | 0.968 |
| City Fixed Effect | YES | YES |
| Year Fixed Effect | YES | YES |

Note: ***, **, and * individually stand for the significance at 1 %, 5 %, and 10 % levels; The standard error of the ro bust cluster at the city level is in parentheses

Table 2 shows the impact of carbon emissions trading policies on labor demand in enterprises. Column (1) shows the average impact of carbon trading policies on labor demand in enterprises without the inclusion of control variables. Column (2) shows the results of further controlling for other variables that affect labor demand in enterprises. The coefficient of the core explanatory variable is -0.134 and is significant at the 5% level. This shows that carbon trading policies have caused employment losses at the enterprise level and reduced labor demand in enterprises. That is, when other control variables are held constant, the implementation of trading policies in pilot enterprises has reduced employment demand by 13.4% compared to non-pilot enterprises.

**Table 2.** Impact of carbon emissions trading on enterprise labor demand

| Variable | FirmLabor | FirmLabor |
|---|---|---|
| | (1) | (2) |
| policy | -0.108 | -0.134** |
| | (0.069) | (0.068) |
| Constant | 7.775*** | 5.626*** |
| | (0.001) | (0.407) |
| Observations | 24,662 | 24,662 |
| R2 | 0.873 | 0.880 |
| Corporate Fixed Effect | YES | YES |
| Year Fixed Effect | YES | YES |

The value in brackets is the robust standard error of the cluster at the corporate level; Same below

## 4.2. Robustness test

### 4.2.1. Parallel trend test

The underlying assumption of the double difference model is that the pre-policy treatment group and the control group have similar trends. In addition, the benchmark regression results test the average impact of the carbon emissions trading system on the labor demand of enterprises during the policy period, and cannot reflect the differences in the impact of the policy from year to year. The event study method, which is often used in conjunction with the double difference method, is widely used to test the parallel trend assumption and the dynamic causal effect of policies (Zhang et al., 2023). Therefore, this paper uses the event study method to assess the dynamic effect of carbon emissions trading on employment.

Following the research of (Deng et al., 2024) ,the first year of the policy was chosen as the base period, and the three years before the implementation of the policy was used as the control group. As the sample size after the implementation of the policy was small after the seventh year, it was combined into the seventh period. The model was built as follows:

$$\mathrm{Labor}_{\mathrm{it}} = \alpha_0 + \Sigma_{t=-3}^{7}\alpha_n policy_{it} + \alpha_2 \mathrm{X}_{\mathrm{it}} + \mu_{\mathrm{i}} + \eta_{\mathrm{t}} + \varepsilon_{\mathrm{it}} \quad (3)$$

The $policy_{it}$ is a dummy variable for the policy. If the enterprise is included in the pilot list and it is the t year after the policy was implemented, then $policy_{it}$= 1; otherwise, it is 0. The coefficient of the core explanatory variable $\alpha_n$ reflects the effect of the policy in the n year and is used to measure the difference between the control group and the treatment group. The meaning of other variables is the same as in Equation (2).

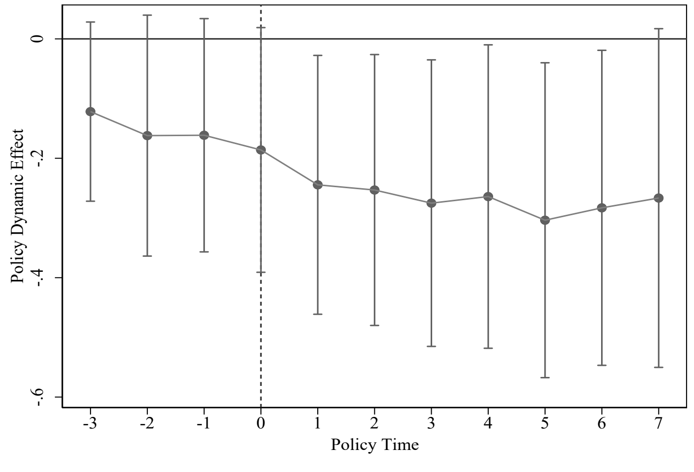


**Figure 1.** Parallel trend test results

### 4.2.2. Heterogeneity-treatment effect test

In recent years, a large number of cutting-edge studies have found that if the time of impact on the treated group is inconsistent, the use of traditional two-way fixed effects (TWFE) estimation may lead to potential bias: the sample that receives treatment earlier will become the control group for the sample that receives treatment later, which may lead to estimation errors(Sun and Abraham, 2021). In order to correct for the potential bias caused by using TWFF in multi-period DID, the analysis in Model (2) is first tested using Bacon decomposition. Then, the "heterogeneity robust estimator" is constructed and re-estimated by drawing on the research methods of Cengiz et al. (2019) and Sun and Abraham (2021).

**Table 3.** Goodman-Bacon decomposition

| DID Group Type | Weight | DID Estimate coefficient |
|---|---|---|
| Early treatment group vs Later control group | 0.001 | 0.084 |
| Later control group vs Early treatment group | 0.002 | -0.496 |
| treatment group vs Untreated control group | 0.998 | -0.107 |

### 4.2.3. Placebo test

To test whether the impact of policies on labor demand is caused by other factors, this paper conducts a placebo test. First, 500 fictitious policy shock times and targets were randomly selected from the sample of all enterprises. The re-estimated coefficient and P-value distribution are shown in. It is not difficult to see from the figure that both the P-value and the estimated coefficient are distributed around 0, and the baseline regression coefficient of -0.134 is much smaller than 0. The P-value is also mostly greater than 0.1. Therefore, it can be considered that the baseline regression results are not affected by other factors, but are caused by the pilot carbon emissions trading policy.

### 4.2.4. Propensity Score Method

There may be self-selection problems in each pilot area when determining the list of enterprises participating in the carbon emission trading pilot, which leads to biased estimation results. Therefore, this paper uses the propensity score matching method (PSM) to calculate the propensity score of enterprises by using control variables as enterprise characteristic variables. The nearest neighbor matching method (1:3) and kernel matching method are used to re-match the control group enterprise samples that are similar to the treatment group. Then, the DID estimation is re-performed using the newly matched samples to mitigate the bias caused by sample self-selection. The results are shown in columns (1) to (2) of Table 4. The estimation results under the two methods show that the implementation of the policy has resulted in a loss of employment at the enterprise level.

### 4.2.5. Other robustness tests

Excluding other concurrent policies. In recent years, the government has introduced a series of environmental protection measures, the most typical of which are the low-carbon city pilot policies implemented in batches in 2010, 2012 and 2017. In order to exclude its impact on the demand for labor by enterprises, this paper constructs a dummy variable for low-carbon city pilot cities and adds it to the benchmark regression to observe whether the coefficients of the core explanatory variables will produce significant differences. The estimation results are consistent with those described above, indicating that the benchmark regression results are still relatively robust after excluding other policy interference.

**Table 4.** Robustness test result

| Variable | Propensity Score (nearest match) | Propensity Score (core match) | Adjust time period | Tool variable | Remove other policy distractions |
|---|---|---|---|---|---|
| | （1） | （2） | （3） | (4) | （5） |
| policy | -0.121* | -0.123* | -0.121** | -0.173* | -0.144** |
| | （0.070） | (0.070) | (0.061) | (0.093) | (0.068) |
| Low-carbon city pilot policy | | | | | 0.055** |
| | | | | | (0.024) |
| Observations | 17865 | 17,394 | 20,298 | 22,002 | 24,662 |
| R2 | 0.879 | 0.881 | 0.893 | 0.056 | 0.880 |
| Corporate Fixed Effect | YES | YES | YES | YES | YES |
| Year Fixed Effect | YES | YES | YES | YES | YES |

## 5. Mechanism testing and heterogeneity analysis

### 5.1. Mechanism test

In order to better understand the impact mechanism of the carbon emission trading system on the labor demand of enterprises, based on the theoretical analysis above, the impact mechanism is tested from three aspects: scale effect, factor substitution effect, and innovation compensation effect. Existing mechanism testing methods can be divided into two categories. The first is the mechanism analysis method, which involves performing a regression analysis between the explanatory variables and the mechanism variables, and the causal relationship between the mechanism variables and the explained variables relies on theoretical explanations (Wen et al., 2014). The second is the stepwise regression method for mediating effects(Jiang et al., 2022). The stepwise method may have problems such as endogeneity and multiple collinearity, so the first method is used for testing.

#### 5.1.1. Scale effect

Since most pilot regions use the principle of free allocation based on historical total emissions for the allocation of carbon emission allowances, traditional high-energy-consuming enterprises still have high carbon emissions, which in turn leads to insufficient liquidity in the carbon market and a weakening of the binding effect of carbon emissions on enterprises. This shows that the carbon emission trading system, as a market-based environmental regulation, is a “gentle” and “gradual” environmental regulation.

### 5.1.2. Substitution effect

From the perspective of capital deepening, the carbon emissions trading pilot policy has increased the capital intensity of enterprises, which has had a factor substitution effect on the labor force. Compared with the obvious shortcomings of end-of-pipe pollution control, such as large capital investment, low economic benefits, and treating the symptoms but not the root cause, front-end environmental regulation has the significant advantage of achieving the dual benefits of ecological protection and economic growth, and has gradually become the new direction of pollution control.

### 5.1.3. Innovation compensation effect

The regression results show that the implementation of carbon emission trading has increased the total factor productivity of enterprises by 9.1%, indicating that the production efficiency of enterprises has been improved, which further verifies Porter's hypothesis. The proportion of R&D personnel decreased by 1.9% compared to before the policy, indicating that compared to the uncertainty and high cost of independent innovation, enterprises prefer to directly purchase production equipment and existing clean technologies to achieve carbon emission reductions.

**Table 5.** Mechanism test result

| Variable | Lnscale | CI | LI | Structure | TFP | RD |
|---|---|---|---|---|---|---|
| | （1） | （2） | （3） | （4） | （5） | （6） |
| policy | -0.096 | 0.060*** | -0.005** | 0.049** | 0.091** | -0.019** |
| | (0.071) | (2.95) | (-2.19) | (0.022) | (2.24) | (0.008) |
| | (0.264) | (-3.86) | (5.60) | (0.151) | (-4.50) | (0.026) |
| Constant | 20.675*** | 3.398*** | 0.297*** | 0.884* | 2.794*** | -0.040 |
| | (0.404) | (18.49) | (18.88) | (0.474) | (9.22) | (0.048) |
| Observations | 24,662 | 24,662 | 24,662 | 23,764 | 24,662 | 24,662 |
| R2 | 0.914 | 0.778 | 0.831 | 0.713 | 0.840 | 0.661 |
| Corporate Fixed Effect | YES | YES | YES | YES | YES | YES |
| Year Fixed Effect | YES | YES | YES | YES | YES | YES |

## 5.2. Heterogeneity analysis

Since the policy pilot areas involve a wide range of industries, covering “two provinces and five cities” and multiple industries, it is easy to be disturbed by other factors when studying the impact of carbon emission trading pilots on the labor demand of enterprises. This paper discusses the differential impact of policies on enterprises from three dimensions: the nature of the enterprise and the degree of emphasis placed on the local environment.

### 5.2.1. Enterprise's ownership

State-owned enterprises have unique resource advantages and strong political connections (Boeing, 2016). Therefore, differences in the nature of enterprise ownership may have a differential effect on policies. This paper divides enterprises into state-owned enterprises and non-state-owned enterprises according to the actual controller of the enterprise, and explores the differences in the impact of policies on different ownership natures.

The results are shown in Table 6. The carbon emission trading system significantly reduced the labor demand of state-owned enterprises, while the policy shock was not significant for non-state-owned enterprises.

### 5.2.2. Heterogeneity in Government's environmental emphasis

As a market-incentive-based environmental regulation, the effectiveness of the carbon emissions trading system depends on the degree of local environmental governance(Hu et al., 2023). The effectiveness of carbon emissions reduction by enterprises varies significantly with the degree of local environmental governance. The higher the degree of local environmental governance, the greater the investment in environmental governance, and the more significant the policy effect of the carbon emissions trading system(Xu et al., 2023).

**Table 6.** Heterogeneity analysis result

| Variable | FirmLabor | | FirmLabor | |
|---|---|---|---|---|
| | State-owned enterprise | Non-state-owned enterprise | Low environmental awareness | High environmental awareness |
| policy | -0.215*** | 0.076 | -0.0626 | -0.466*** |
| | (0.078) | (0.101) | (0.0734) | (0.127) |
| Constant | 7.276*** | 5.384*** | 5.831*** | -0.466*** |
| | (0.601) | (0.564) | (0.438) | (0.127) |
| Observations | 12,424 | 12,238 | 20,182 | 4,479 |
| R2 | 0.890 | 0.861 | 0.880 | 0.881 |
| Corporate Fixed Effect | YES | YES | YES | YES |
| Year Fixed Effect | YES | YES | YES | YES |

## 6. Main findings and policy implications

This paper uses the pilot policy of carbon emission trading as a “quasi-natural experiment” to empirically examine the impact of market-based environmental regulation on labor demand using macro data at the prefecture level and micro data of listed companies. The main findings are as follows. First, there are significant differences between the micro and macro levels in the impact of the carbon emissions trading system on labor demand. Although the policy has caused a decrease in labor demand in enterprises, it has increased urban employment.

Improve the carbon emission trading system and optimize the carbon quota allocation mechanism. Judging from the results of the benchmark regression, it will have a negative impact on the labor demand of enterprises, resulting in a loss of social welfare. However, the existing “historical method” carbon quota allocation plan fails to reflect the differences between highly polluting enterprises and green enterprises, resulting in unnecessary unemployment. To avoid unnecessary losses in social welfare, the government needs to strengthen top-level design and allocate carbon quotas to enterprises according to the “industry benchmarking method”, so that the intensity of environmental regulation on enterprises is consistent with their own pollution levels.

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