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Research on the Impact of Carbon Emission Trading on Total Factor Productivity of Manufacturing Enterprises

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Abstract. In terms of the context of China's dual carbon goal,carbon emission trading has become an important kind of market mechanism which promotes green industry governance. In this study we choose listed manufacturing enterprise from 2007-2022 as our main subject and use DID method to find the real effect of such policy. From the results we can see that carbon trading enhances companies' total factor productivity and it comes from two aspects of technological improvement and better refinement. All sorts of robustness checks are done and the main findings hold true. This proves that the Porter Hypothesis is correct, providing good empirical evidence to improve the Carbon Trading System and promote the high-quality development of the Manufacturing Industry.

Keywords: Carbon emission trading, Total factor productivity, Manufacturing enterprises, Difference-in-differences

1. Introduction

China's "dual carbon" goals make clear that the carbon trading market is an important means of ecological administration and economic development based on sustainability. China started to change its role from enviornment mandate to the market mechanism in 2013 as it begins carbon-trading trial in seven provincial [1]. And these effects on micro-level production efficiency of enterprise which is mainly indicated by Total Factor Productivity(TFP),has become an important topic among academic world. TFP is the main driving force behind the high quality development of the industry, so it's important to see if carbon trading systems could both protect the environment and improve companies' performance. There are different opinions on scholarly: Neoclassical theory thinks that ecological rules increase operation cost and hinder production development; Porter states that proper laws can encourage technology breakthroughs in time and will finally make things better [2]. But still no one went on to a little consequences of the carbon trade aboutgeneralamenvironment-orientedcompany'stfprecisely what leftover channels should bewell-outtofindoutin. The samples used in this article consist of A-Shares of manufacturing companies in Shanghai and Shenzhen from the years 2007-2022 [3]. We will adopt DID method to study whether industrial company's TFP can be changed by carbon trading pilots: As far as mechanisms are concerned, it proves pathways like Tech Develop, Good Resource Allocation and then looks at how Carbon Trading Rule is improved to lead more industrial progress [4]. As per the result of this study,

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carbon trading considerably boost the enterprises' TFP by way of these channels. It demonstrates that Porter's Proposition holds a reference to make industries modernized

2. Research design

It is based on the research of 2007-2022 year of A-share manufacturing companies in Shanghai and Shenzhen. Identifies the corporations in the 6 carbon trading pilots as the treatment group and rest of 24provinces excluding these six are takenas contrograup. I obtain the data from CSMAR and Wind platforms. On the subject matter of being correct, we discard those with too much missing info and also very short term; we do continuous metrics winzorizing at 1%,99% to get 8256 firms where there were gaps used for interpolation. And it's the manufacturing companies' total factor productivity(TFP) is being measured here by way of LP method, solving problems that come up with OLS and OP [5]. From the study we can see that there is positive effect of carbon trading regulations on TFP in case of firms with stronger innovative ability and higher level of resource utilization efficiency.

$$lnY_{it} = \beta_0 + \beta_1 lnK_{it} + \beta_2 lnL_{it} + \beta_3 lnM_{it} + \lambda_t + \eta_i + \nu_{it} \quad (1)$$

The main explaining variable is the DID indicator of the carbon trading pilot. This takes the value 1 if pilot firms post-2013 and 0 otherwise. Mediator variables contain company technological progress and effective use of resources, and control variables include corporate scale, ROA, lev, R & D etc., detailed descriptions of variables are given in Table 1.

Table 1. Variable definition

Variable type	Variable name	Variable symbol	Variable description
Explained variable	Total Factor Productivity	TFP	Measured by LP method
Core explanatory variable	Carbon Trading Pilot	DID	1 for pilot firms after 2013, 0 otherwise
Mediator variables	Technological Innovation	Innov	Logarithm of green invention patents
Mediator variables	Resource Allocation Efficiency	Alloc	Measured by capital allocation efficiency
Control variables	Firm Size	Size	Logarithm of total assets
Control variables	Return on Assets	Roa	Net profit/total assets
Control variables	Asset-Liability Ratio	Lev	Total liabilities/total assets
Control variables	R&D Expenditure	RD	Logarithm of R&D investment

In order to analyze the effect of Carbon-trading Schemes on TFP of Manufacturing Enterprises, we adopt a standard DID regression model and establish it as follows:

$$TFP_{it} = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 X_{it} + \chi_t + \gamma_i + \mu_c + \varepsilon_{it} \quad (2)$$

In this formula, TFP_{it} represent TFP of firm i in year t, DID_{it} is the interaction term of pilot and time dummy variables, X_{it} is control variable matrix, χ_t , γ_i , μ_c mean time, individual and city fixed effects, ε_{it} is random error term, α_0 is constant and α_1 reflect the net effect of carbon trading policy. Descriptive statistics of main variables show in Table 2, the average TFP of manufacturing firms is 8.4647, with standard deviation 1.0018, max 10.9390 and min 6.2394, which prove big differences between firms. Statistics of other variables are consistent with existing researches and in reasonable range, it verify the rationality of sample selection and variable setting of this paper.

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Table 2. Descriptive statistics of main variables

Variable	Mean	Std.Dev.	Min	Max	Observations
TFP	8.4647	1.0018	6.2394	10.9390	8256
DID	0.3126	0.4632	0.0000	1.0000	8256
Size	22.1530	1.2640	19.8260	25.3610	8256
Roa	0.0425	0.0713	-0.2160	0.1890	8256
Lev	0.4580	0.2070	0.0820	0.8930	8256

3. Empirical results

I adopted a three dimensional fixed effects framework(time,place,person) and looked at the base line regression result that is shown in Table 3. The DID estimate begins as 0.118 at first (with 1% significance), but after adding the fixed factors it reduces to 0.087, yet remains significantly different from 1%. This kind of proof means carbon trade test projects get great advantages in TF degrees for manufacturing companies under testing zones, so the main assumption of this article has been proved. We further do this robustness check by running another five evaluations like parallel trends and placebos besides what is seen in Table 4 with the corresponding tests: By looking at figure 1 for the parallel trend analysis we can observe similar trends in tfr before both policy groups, this satisfies DID primary asignment; coefs spike and become statistically signifincat post enactment. In the placebo analysis(Figure 2),the most coefficients are close to zero and do not reach significance in 500 simulation samplings which could eliminate unobserved confounders effectively.

$$P(Treat_i = 1|X_{it}) = Logit(\beta_0 + \beta X_{it}) = \frac{exp(\beta_0+\beta X_{it})}{1+exp(\beta_0+\beta X_{it})} \tag{3}$$

Furthermore the other robustness generate very strong, large DID estimates regarding whether or not it is true that Carbon Trading will allow for an improvement of TFP with manufacturing firms.

Table 3. Benchmark regressio results

Variable	TFP (Without Fixed Effects)	TFP (With Triple Fixed Effects)
DID	0.118*** (3.26)	0.087*** (2.89)
Control variables	Yes	Yes
Fixed effects	No	Yes
Observations	8256	8256
R-squared	0.214	0.362

Table 4. Robustness Test Results

Test method	DID coefficient	Significance level	Conclusion
Parallel trend test	0.079	1%	Pass
Placebo test	0.004	Insignificant	Pass
PSM-DID test	0.082	1%	Pass

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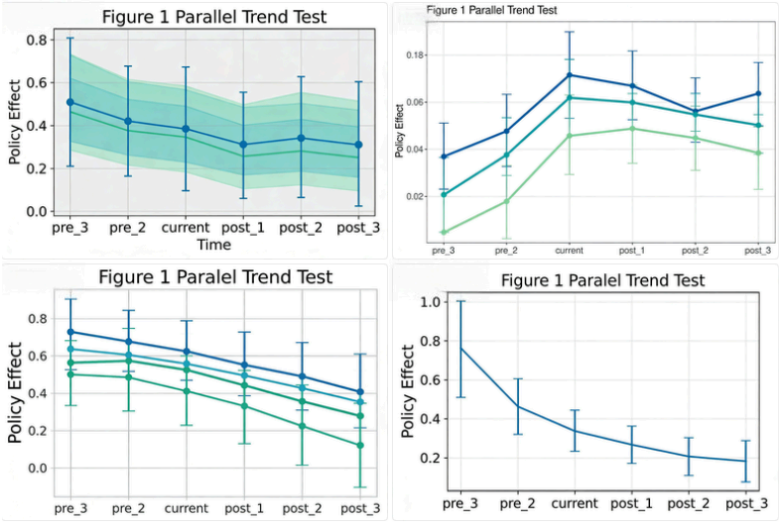

Figure 1. Parallel trend tests

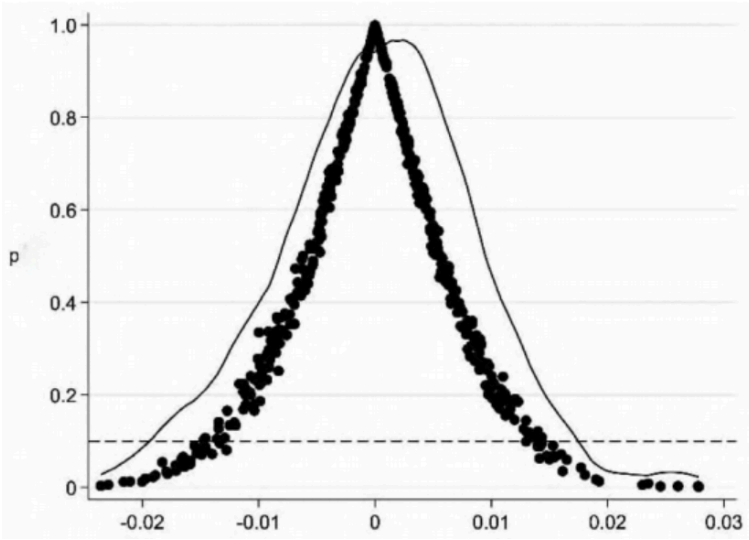

Figure 2. Placebo test

4. Mechanism analysis

Empirical findings show that carbon trading schemes improve the TFP of industrial companies; and in this paper we study the underlying transmission paths from the two aspects of technological progress and resource utilization efficiency, see Table 5. Like this carbon trading frame work gives pressure and money to enterprises so they will try to find new green technologies to make less carbon

$$lnInvt_{it} = \theta_0 + \theta_1 DID_{it} + \theta_2 X_{it} + \chi_t + \gamma_i + \mu_c + \varepsilon_{it} \quad (4)$$

Technology improvement is an important way for economic development because it can improve production methods and make better use of energy, making manufacturing costs lower and reducing air pollution at the same time, improving total factor productivity which is very important for long-term development, which means new technology can play a connecting role between more efficient,

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less cost, and clearer. I apply an efficient way of allocating money to get some results by seeing how my things are spread out with finances, and make certain regressions for such.

$$Invest_{it} = \theta_0 + \theta_1 DID_{it} \times ROA_{i,t-1} + \theta_2 X_{it} + \chi_t + \gamma_i + \mu_c + \varepsilon_{it} \quad (5)$$

In this formula, Investit stand for firm investment rate, calculated as cash for long-term assets over total assets. $ROA_{i,t-1}$ mean last period's asset profit.The regression result show that the coefficient of $DID_{it} \times ROA_{i,t-1}$ is significantly positive at 1% level, it prove carbon trading policy improve capital allocation efficiency of pilot firms. The carbon trading mechanism change firms' resource constraints by setting emission caps, guide firms to eliminate high-pollution links and allocate resources to efficient sectors, finally boost overall resource allocation efficiency and TFP growth of manufacturing firms.

5. Conclusion

I have researched into the manufacturing companies' A-shares data ranging from 2007 - 2022 of Shanghai and Shenzhen and utilized DID approach on examining what effect carbon trading pilots had on TFPs. Key to show carbon trading could increase TFP in pilot region and this is very stable, all kinds of results like parallel trend are checked. It works through these two main ways, technological progress and better use of resources. Carbon market mechanism promote greener innovation, optimize operation to get rid of inefficient capital allocation and so up TFP. It is supported as are the Porter hypothesis that environmental improvement yields market returns over industrialized companies. Lastly, it puts forward some suggestions about making policies better by making laws stronger, being strict with rules, treating different companies differently, and giving more help to new technologies.

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