The Effect of Emission Trading on Industry Structure, Cutting overcapacity of Different Size Firms and Industry Orientation: Evidence from a Quasi Natural Experiment in China

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Abstract: This paper analyzes the effect of emission trading on industry structure and cutting overcapacity in firms of different sizes, using a quasi natural experiment in China. The Chinese government implemented a pilot policy for emissions trading in 2007, assigning 11 provinces of all 34 provinces as pilots for trading emission rights, which can be treated as an excellent quasi natural experiment. I collect two panel data sets of different levels, respectively containing 30 provinces and all 281 prefecture-level cities of these provinces from 2003 to 2017. The causality of emission trading on industry structure, cutting overcapacity of different sizes firms and industry orientation is identified by DID method. Based on the empirical results, I find that 1) the effect of emission trading on changes in industry orientation is not significant, 2) emission trading mainly lays effect on small firms by reducing their capacity and outputs rather than industrial enterprises above designated size, 3) the productive factors and resources outflowing from eliminated inferior capacity of small firms probably divert into the third industry, i.e. so called service industry. [1]

Key words: DID Method; Emission Trading in China; Industry structure; Heterogeneity effect of Cutting Overcapacity

Introduction

Taking social cost into consideration, (Coase, 1960) pointed out that the allocation of emission rights through the market is the most efficient mechanism to solve pollution problems. (Ｍontgoｍery, 1972) proved theoretically that the emission trading mechanism can effectively control the cost of emission reduction, which is significantly better than the traditional command-control mechanism. As emission trading is considered to be an efficient environment regulation policy, developing countries like China started to put it into practice decades ago. The emission trading policy in China was first promoted in 2002 by assigning some cities as pilots, but in this period, however, emissions trading activity is very low (曹静 et al., 2019). To improve this situation, in 2007, the Ministry of Finance, the former Ministry of Environmental Protection and the National Development and Reform Commission of the People's Republic of China formally approved 11 provinces (cities)[2] to become the pilots of emission trading, and each pilot province (city) also issued relevant policy documents to ensure the conduct of emission trading, which is used as a quasi natural experiment to identify causal effect of emission trading.

[2]Tianjin, Hebei, Shanxi, Inner Mongolia, Jiangsu, Zhejiang, Henan, Hubei, Hunan, Chongqing and Shaanxi

Most studies on emissions trading are focused on theoretical studies on the design of mechanisms. (Hudgins and Yoskowitz, 2010) try to solve the effective emissions of countries under uncertain conditions such as cost and price by establish models, they believe that emissions quantities should be assigned based on market, a regulatory system and a penalty mechanism should be set up, and new technologies that promote emissions reduction should be funded. (Stein 2010) believes that the effectiveness of the emission trading mechanism needs to be achieved by combining the stability of long-term goals with short-term policies based on taxation, trading, or certain regulations. (Lambie, 2010) believes that the credibility of emissions trading schemes and the certainty of policies will affect the investment behavior of enterprises and the creation of low-emission technologies. (Betsill and Hoffmann, 2011) believe that the emissions trading mechanism is effective in reducing greenhouse gas emissions, but there is still uncertainty about who should be responsible for formulating total control volume and trade rules and what these rules should be. When designing total control volume and trading systems, one of the most controversial issues is how to distribute licenses and how to conduct free distribution or auctions. (Fare et al., 2013) expanded the trading form of pollutant emission rights, not only considering the potential economic benefit of emission rights in spatial trading (transactions between different producers at the same time), but also considering the intertemporal trading of emission rights (unused pollution permits can be deposited in trading institutions for potential economic benefit for use or resale in the next period). (范进 et al., 2012) incorporated consumption factors into the emission reduction framework, and established a rationale for carbon emissions trading using the method of experimental economics to find that emissions trading can encourage consumers to choose low-carbon products, thereby reducing carbon emissions. And there are also a lot of other researches on the theory and mechanism of emissions trading in China, such as (王勤耕 et al., 2000), (马中,Dan Dudek et al., 2002), (鲁炜 et al., 2003) and (施圣炜 et al., 2005) et al.. These papers discussed a series of issues related to emissions trading under Chinese conditions from various perspectives.

The political effect analysis is relatively rare, and research conclusions are inconsistent. (Schleich and Betz, 2004) found through experimental simulation that the emission permit trading system has a positive effect on the emission reduction of small and medium enterprises, but the emission reduction effect depends on the authenticity of the emission level reported by the enterprise. (Anderson et al., 2010) used empirical methods to study the impact of EU carbon emissions trading on carbon dioxide emissions reduction in manufacturing, and the results showed that companies participating in the emissions trading framework have relatively greater possibilities for environmental innovation. On the other hand, some scholars believe that the effects of pollution rights policies are limited. (Hoffmann, 2007) conducted an empirical analysis of the EU's emissions trading system through a dynamic panel model. The study tried to decompose two reasons for emission reductions: one is the emission reduction achieved by the emission rights, and the other is the emission reduction achieved by the 2008 economic crisis. The results show that it is the economic crisis that plays a dominative role in reducing emissions.

The empirical papers about Chinese emission trading policies emerging in recent years. (李永友 and 沈坤荣, 2008) studied the emission trading pilot policy in 2002, and found that emissions trading in some pilot regions has not yet shown its positive effects in terms of emission reduction. (涂正革 and 谌仁俊, 2015) used province level panel data between 2002-2012, and also found that the emission trading pilot policies failed to produce a ”Porter effect”[3] in China, and the inefficient market cannot support the operation of the emission trading mechanism. The empirical papers in the past few years mainly focus on direct effects, sulfur dioxide emission reductions, and indirect effects, the effect on some dimension of economy. (张宁 and 张维洁, 2019) believe that emissions trading does not have significant emission reduction effects in pilot areas, but it is undeniable that there will be long-term economic and environmental benefits. However, (李永友 and

[3](Porter, 1991), (Porter and ven der Linde, 1995) and (Ambec and Barla, 2002) believe that reasonable and strict environmental regulations can encourage enterprises to carry out more innovative activities to enhance their productivity and competitiveness, and compensation from innovation can partially or fully compensate for the additional costs caused by environmental protection.

文云飞, 2016) drew an opposite conclusion against Zhang that pollution emission trading has a significant emission reduction effect in pilot areas, which is inseparable from a good institutional environment of emission trading. It is the role of market mechanism that causes the emission reduction effects of emission rights trading in pilot areas. (任胜钢 et al., 2019) found that the emission trading system significantly increased the total factor productivity of listed companies in the pilot areas and the effect increased from the lagged two years on. (史丹 and 李少林, 2020) studied the effect of trading emission on energy efficiency, and found that emission trading system can significantly reduce energy consumption per unit of GDP and increase green full factor energy efficiency rate.

This paper presents some marginal contributions to the former literature in three ways. First, regardless of whether it is domestic or foreign, most of the literature on emissions trading is based on models and theoretical analysis, empirical researches based on quasi natural experiment which is limited by policies implementation are prosperous in recent two years. Especially in China, it is until recent years that enough data can be collected to analyze the causal effect of emission trading. So, this paper takes developing countries, like China witch is not only typical in pollution and economic growth among all developing countries, but also a vital important composition of globalization who spares no efforts to mitigate pollution problems, as the research object, which is meaningful to existing literature. Second, based on the combed literature, this paper may be the first to study the effect of emissions trading on industrial structure, heterogeneity of overcapacity reduction, and industry orientation. This paper takes the lead in researching emission trading from an industry perspective, and examines its impact on China's hot topics, overcapacity reduction, in recent years. Third, this paper not only adopts a quasi natural experimental strategy, DID method, to identify causal effect of emission trading, but also conduct various robustness test, using IV, PSM DID, et al.. This paper is the first one in literature on Chinese emission trading to take heteroskedasticity, autocorrelation and cross sectional correlation into consideration, which results in quite convincing conclusions of this paper. Besides, the pilots which were added a few years ago and were later removed are eliminated in this paper, resulting an even more robust and accurate result.

In section 1, I will introduce the data of this empirical research. Section 2 presents the identification strategy and main results. Section 3 details robustness tests. And in section 4, I carry out mechanism analysis and heterogeneity analysis. At last, section 5 concludes the paper.

1 Data

The province level panel data set from 2003 to 2017 is collected from all kinds of Chinese statistical yearbooks which are available from the China Economic and Social Big Data Research Platform of https://data.cnki.net/YearData/Analysis, the official website, https://data.stats.gov.cn,of National Bureau of Statistics, and China Microeconomic Data Query System of http://microdata.sozdata.com/home.html. And the prefecture-level data set from 2003 to 2017 are based on the paper of (史丹 and 李少林, 2020). Of course, I made some adaptions according to this paper's needs. I will present some critical variables in the following part.

1.1 Industry structure, industry orientation and measurement of over capacity reduction

This paper takes the proportion rate of tertiary industry output value and secondary industry output value as the measurement of industry structure in province level data, and the proportion rate of outputs of Industrial enterprises beyond quota in GDP and the proportion rate of the added value of the secondary industry in GDP as the measurement of industry structure in prefecture-level data. The relative variable names are $lnindustruco$, $lnindgdp$ and $erchan$.As for the measurement of over capacity reduction in different size firms, I cannot find a proper index to describe, but this effect can be deduced from the relative change between the proportion rate of outputs of Industrial enterprises on quota in GDP and the proportion rate of the added value of the secondary industry in GDP. The industry orientation is defined as the ratio of the total output value of green development industrial enterprises to the total output value of all industrial enterprises, called *lnindsorien*. The green development companies are government-certified companied with unique green development identification codes, which can be used as a green industry-oriented indicator.

1.2 Treat group, control group and time period

Since the emission trading policy was implemented in 2007, I conduct dummy variables: *time* in province level data and *post* in the prefecture level data, which both take the value 1, when the year is greater than 2007, and take the value 0, when the year is less than 2007. To identify the treatment group, I conduct a dummy variable, *treat*, whose value takes 1 when the provinces or the prefecture-level cities are in the list of emission trading pilots. And I also generate dummy variables of cities (or provinces) and years to identify fixed effect.

1.3 Control variables

Based on the former literature, I find varieties of control variables for both province and prefecture-level city data. They are listed in Table 1 and Table 2:

Measurement	Variable name	Economic meaning
Night light brightness	lnenergy	Energy consuming
Sulfur dioxide emissions	lnso2	Pollution level
GDP per capita	lnpgdp	The level of economic development
Population density	lnpeoplemidu	Human activity scale
Number of registered patents	lnpatent	Innovation
Energy consumption per unit of GDP	lngdpenergy	Energy efficiency

Table 1: Controls for prefecture city data

Measurement	Variable name	Economic meaning
Number of registered high-tech patents	lnpatent	Innovation
Industrial sulfur dioxide emissions	lnindustryso2	Pollution level
Percentage of imports and exports in GDP	lntradedep	Difficulty of transition
Coal energy consumption	lnenergy	Energy consuming
Proportion of urban population	lncitypopupro	Population structure
GDP per capita	lnpgdp	The level of economic development
Fiscal expenditure as a percentage of GDP	lnfistru	The degree of government intervention in the economy

Table 2: Controls for province data

1.4 Statistical description

In Table 3 and Table 4, I show the statistical characteristics of important variables in this paper.

variable	mean	sd	min	max
erchan	0.480	0.110	0.0900	0.910
lnindgdp	0.320	0.670	-4	3.210
lnenergy	6.760	0.920	3.610	9.430
lnso2	10.47	1.130	0.690	13.43
lnpgdp	8.460	0.750	6.070	13.82
lnpeoplemidu	5.710	0.890	1.680	7.890
lnpatent	6.170	1.840	0.690	11.58
lngdpenergy	0.170	0.840	-1.810	4.140

Table 3: Statistical characteristics of city data

variable	mean	sd	min	max
lnindustruco	-0.0600	0.370	-0.640	1.450
lnindsorien	-2.110	1.360	-3.750	4.700
lnpatent	6.150	2.210	0	11.34
lnindustry 2	12.84	1.380	6.620	14.36
lntradedep	5.560	0.990	3.280	7.780
lnenergy	9.160	0.790	6.140	13.82
lncitypopu o	3.900	0.290	3.010	4.500
lnpgdp	9.090	1.150	5.220	11.40
lnfistru	7.610	0.500	6.670	9.540

Table 4: Statistical characteristics of province data

2 Identification strategy and main results

Base on the former literature, like (史丹 and 李少林, 2020), (任胜钢 et al., 2019) and (余泳泽 et al., 2020), this paper sets the DID models as Eq. 1 ∼ 4.

$$lnindustruco_{it} = \alpha_0 + \beta(treat_i \times time_t) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{1}$$
$$lnindsorien_{it} = \alpha_0 + \beta(treat_i \times time_t) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{2}$$
$$erchan_{it} = \alpha_0 + \beta(treat_i \times post_t) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{3}$$
$$lnindgdp_{it} = \alpha_0 + \beta(treat_i \times post_t) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{4}$$

The variables in the equations above most has been introduced in the data part. λ_i is the location fixed effect, γ_t is the time fixed effect and ε_{it} represents the random error term varying with location and time.

As is known, there are several stata commands that can be used to conduct DID estimation. The most common and convinient one may be $diff$ by (Villa and J.M., 2016). However, the concern that the panel data may have heteroskedasticity, autocorrelation and cross-sectional correlation, in which situation the command $diff$ is no longer applied, must be testified. So before estimation, I conduct a serials of tests to verify whether this concern exists or not. By using $xtserial$ command, I find that both province and prefecture city data have the autocorrelation problem. By using $xtcsd$ command to conduct Pesaran test, friedman test and Frees test, I find that the province level data have the problem of cross sectional correlation, but the prefecture city data does not have the concern problem. And at last, by using $xttest3$ command, I find that both data sets have the concern of heteroskedasticity. Based on the above mentioned tests, the $cluster$ robust standard error method is adopted in the DID estimation of prefecture city data, and the $xtscc$ estimation method is prosper in the situation of province data set. By using relative methods, the DID estimation results are reported in Table 5 and Table 6.

A logical deduce can be conducted based on the results in Table 6. First, let us concentrate on column (2) and column (4), and it is not hard to find that both results are not statistically significant, which points out that the effect of emissions trading policies on large companies is not large enough. But it is surprising to find out that the coefficients of did in column (1) and column (3) are not positive, which indicates that the production capacity and outputs of small firms reduce under the influence of emissions trading. This is because when the total output of the manufacturing industry decreases and the output of large manufacturers does not decrease, the reduction can only come from small manufacturers. And this effect is significant. The coefficient of did in column (1) is significant at 10% level, and the significance level increases to 1%, when the control variables are included. From Table 6, it is apparent to draw the conclusion that whatever condition is, the coefficients of did of dependent variable , $lnindsorien$, are not statistically significant, which indicates that at least at province level, emissions trading has no influence on the green orientation of the industry. The concern that whether the insignificant result remains at the city level deserves further investigating, but constrained by data, this paper does not involve this discussion. But from column (3) in Table 6, we can find that the coefficient of interest is positive and of 1% significance. The transparent economic meaning of this result is that the proportion of the tertiary industry increases relative to that of the secondary industry, that is, the industrial structure upgrades. This result can be related to the results in Table.5 that due to emissions trading, some small firms decrease production capacity, so that the production factors and resources transfer from the secondary industry to the tertiary industry resulting in relative increase in the output of the tertiary industry. But this effect is not robust (it fails in the later robustness test part), so here this paper only puts forward a conjecture on the interpretation of this result. All in all, the results of these two tables can be explained as: emissions trading has a heterogeneous effect on capacity reduction, and the effect of capacity reduction is mainly reflected in small manufacturers, the transfer of production factors and resources from the secondary industry to the tertiary industry leads to the upgrading of the industrial structure, but the green production orientation of the secondary industry itself do not

Table 5: DID estimation results of prefecture city data

	Without Control		With Control	
	(1)	(2)	(3)	(4)
	erchan	lnindgdp	erchan	lnindgdp
did	−0.0141*	−0.0287	−0.0190***	−0.0339
	(0.0081)	(0.0397)	(0.0066)	(0.0362)
lnenergy			0.0327***	0.0432
			(0.0079)	(0.0374)
lnso2			0.0046	0.0431**
			(0.0033)	(0.0182)
lnpgdp			0.0968***	0.3666***
			(0.0214)	(0.0813)
lnpeoplemidu			−0.0275	−0.0399
			(0.0194)	(0.1101)
lnpatent			0.0104***	0.0045
			(0.0039)	(0.0191)
lngdpenergy			−0.0361**	0.1098
			(0.0181)	(0.0826)
_cons	0.4559***	−0.3853***	−0.4086*	−3.7320***
	(0.0036)	(0.0192)	(0.2101)	(0.9934)
City fixed effect	*Yes*	*Yes*	*Yes*	*Yes*
Time fixed effect	*Yes*	*Yes*	*Yes*	*Yes*
N	4215	4215	4215	4215
R^2	0.189	0.695	0.382	0.731

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: DID estimation results of province data

	Without Control		With Control	
	(1)	(2)	(3)	(4)
	lnindustruco	lnindsorien	lnindustruco	lnindsorien
did	−0.0064	0.0013	0.0564***	−0.0052
	(0.0138)	(.)	(0.0183)	(0.0313)
lnpatent			0.0011	−0.0218
			(0.0058)	(0.0164)
lnindustryso2			0.0279*	−0.0973*
			(0.0146)	(0.0434)
lntradedep			−0.0095	0.0429
			(0.0168)	(0.0291)
lnenergy			0.1145	0.3201*
			(0.0789)	(0.1697)
lncitypopupro			−0.0455	−0.6532
			(0.1588)	(0.3861)
lnpgdp			−1.0821***	−0.8858***
			(0.0924)	(0.0731)
lnfistru			0.0231	−0.3649**
			(0.0689)	(0.1408)
_cons	−0.0558***	−2.0565	7.4880***	8.5484***
	(0.0000)	(.)	(0.9948)	(1.9580)
City fixed effect	*Yes*	*Yes*	*Yes*	*Yes*
Time fixed effect	*Yes*	*Yes*	*Yes*	*Yes*
N	465	227	368	178
R^2				

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

change significantly.

3 Robustness test

The model setting and estimation methods in this paper are difficult to avoid endogenous problems such as omitted variables, measurement error et al.. For an instance, other environment regulations may act as omitted variables in this paper's model. First, emission trading, as a kind of environmental regulation policy, will definitely work in conjunction with other environmental regulations, in other words, they are correlated. Second, there are sufficient evidences, such as(童健 et al. 2016) and (余泳泽 et al., 2020), showing that there is a strongly robust connection between environment regulation and industry structure. So, other environment regulations are on kind of omitted variables. However, as a policy analysis, it is difficult to find all omitted variables accurately and have access to the data, so it is of vital importance to comprehensively testify whether the endogenous problems exist or not, and compare results of DID method to other identification strategies. In this part, I conducted a variety of robustness tests to prove that the results and conclusions obtained earlier in this paper are robust and convincing.

3.1 Parallel trend test, lags and expectations

One of the most important premise of using DID method is the parallel trend hypothesis. To simply testify whether or not this hypothesis holds in the two data sets, Fig. 1 is displayed.

(a) City data parallel trend test

(b) Province data parallel trend test

Figure 1: Parallel trend test

As can be seen in the Fig. reffig:parallel, the trends of the treatment group and the control group of the two data sets are roughly the same. But under such a rough test, there are still concerns that the hypothesis of parallel trends does not hold. To further testify the parallel trend hypothesis, the Eq. 5 and Eq. 6 are conducted.

$$erchan_{it} = \alpha_0 + \sum_{k=2003}^{2017} \beta_k (treat_i \times post_k) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{5}$$

$$lnindustruco_{it} = \alpha_0 + \sum_{k=2003}^{2017} \beta_k (treat_i \times time_k) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{6}$$

Where $post_k$ represents a dummy variable whose value takes 1 when *year* equals k. And the results of the two regression equation are showing in Fig. 2

In Fig.2, the position of the points represent the coefficient value, and the lines of different thicknesses represent the confidence intervals with different significance levels. As can be seen from Fig.2, whether it is city or province data, coefficients have positive or negative values, and the fluctuations are relatively random.In the city data, the confidence intervals of most points contain 0, which means that no lag or expected effects are found in the city data, and its parallel trend hypothesis is confirmed. But in the province data, the confidence

(a) Results of Eq. 5 (b) Results of Eq. 6

Figure 2: Parallel trend test

intervals of many points do not contain 0, which means that the coefficients represented by these points are not 0 at 1% significant level. In the provincial data, it is still doubtful whether the parallel trend hypothesis is passed. Based on the above tests of the parallel trend hypothesis, the conclusions obtained in the prefecture cityl data are robust, but the results obtained in the provincial data are doubtful.

3.2 Placebo

3.2.1 Change the year of policy implementation

First of all, this paper conducts a placebo test of changing the treatment year. This paper selects the middle year between the actual treatment time and beginning time of the the data as the placebo treatment year, and conducted the same DID model again. The results are listed in Table 7.

Table 7: Year placebo test

	Prefecture Cities	Provinces
	(1)	(2)
	erchan	lnindustruco
did2005	-0.0058	0.1576
	(0.0049)	(0.0663)
_cons	-0.4318^{*}	-33.4429
	(0.2519)	(17.4591)
controls	*Yes*	*Yes*
City fixed effect	*Yes*	*Yes*
Time fixed effect	*Yes*	*Yes*
N	843	40
R^2	0.197	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

It is easy to see from the Table 7 that in both column the coefficients of policy effect in 2005 are not significant, which shows that both the city data and the province data pass this placebo test.

3.2.2 Balance test

This paper also conducts balance test for both of the data sets. And the results are displayed in Table 8 and Table 9. It is easy to see that the city data passes the balance test but the provincial data does not.

Table 8: Balance test for prefecture city data

	(1) lngdpenergy	(2) lnenergy	(3) lnso2	(4) lnpeoplemidu	(5) lnpatent
did	−0.0302	0.0398	−0.2065***	−0.0142	−0.0887
	(0.0171)	(0.0297)	(0.0600)	(0.0084)	(0.0703)
lnenergy	0.1271***		0.0789	0.0117	0.0591
	(0.0178)		(0.0638)	(0.0071)	(0.0556)
lnso2	0.0163	0.0205		−0.0037	0.0372
	(0.0085)	(0.0168)		(0.0050)	(0.0270)
lnpgdp	−0.2580***	0.2555***	0.1388	−0.0362***	0.0328
	(0.0571)	(0.0571)	(0.0787)	(0.0121)	(0.0624)
lnpeoplemidu	−0.2839***	0.1451	−0.1745		−0.1654
	(0.0848)	(0.0886)	(0.2441)		(0.1625)
lnpatent	−0.0099	0.0222	0.0537	−0.0050	
	(0.0104)	(0.0209)	(0.0385)	(0.0046)	
erchan	−0.2504*	0.8951***	0.4814	−0.0605	0.7549**
	(0.1237)	(0.1903)	(0.3601)	(0.0404)	(0.2845)
lngdpenergy		0.5014***	0.2473	−0.0901***	−0.1043
		(0.0754)	(0.1300)	(0.0197)	(0.1090)
_cons	3.2142***	2.4139***	9.1968***	5.9818***	4.3853***
	(0.6647)	(0.7078)	(1.4644)	(0.1087)	(1.2129)
City fixed effect	*Yes*	*Yes*			
Time fixed effect	*Yes*	*Yes*			
N	4215	4215	4215	4215	4215
R^2	0.760	0.660	0.375	0.241	0.872

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.005$

Table 9: Balance test for province data

	(1) lnpatent	(2) lnindustryso2	(3) lntradedep	(4) lncitypopupro	(5) lnpgdp	(6) lnfistru
did	0.3147***	−0.1754*	−0.1238***	0.0296***	0.0130	−0.0595**
	(0.0345)	(0.0731)	(0.0346)	(0.0030)	(0.0100)	(0.0185)
lnindustryso2	−0.0388		−0.3008***	0.0613***	−0.0302	−0.0004
	(0.1186)		(0.0358)	(0.0123)	(0.0211)	(0.0329)
lntradedep	0.0986	−0.2060***		0.0586***	−0.0184	0.0232
	(0.0622)	(0.0524)		(0.0105)	(0.0169)	(0.0377)
lnenergy	0.2310	0.7583***	0.0809	−0.0852*	0.4628***	0.2778***
	(0.3028)	(0.1790)	(0.1803)	(0.0325)	(0.0561)	(0.0598)
lncitypopupro	1.1338*	1.6826*	2.3506***		0.7695***	0.4301***
	(0.4908)	(0.6026)	(0.2072)		(0.0604)	(0.1108)
lnpgdp	0.1064	−0.3316	−0.2953	0.3075***		−0.4043***
	(0.4238)	(0.2719)	(0.2517)	(0.0349)		(0.0610)
lnfistru	−0.0029	−0.0027	0.2272	0.1049*	−0.2468*	
	(0.4566)	(0.2208)	(0.3458)	(0.0430)	(0.0967)	
lnpatent		−0.0048	0.0178	0.0051	0.0012	−0.0001
		(0.0138)	(0.0102)	(0.0032)	(0.0045)	(0.0084)
_cons	−2.5083	3.9257*	0.4138	0.0745	3.6030***	6.4398***
	(5.0184)	(1.6634)	(2.4813)	(0.3871)	(0.7479)	(1.0834)
N	368	368	368	368	368	368
R^2						

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.005$

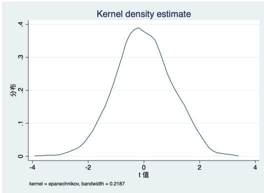
It can be seen from Table 8 that, except for the case where sulfur dioxide is used as the dependent variable, the policy effects in all other cases are not significant at the 5% level of significance, which shows that the city level data basically passed the balance test, and the main effect of the implementation of the policy is the factor that this paper is of interest. As for the significant effects of emission trading on sulfur dioxide emissions, this may be the mechanism by which policies act on key variables, which will be further verified in the mechanism analysis section.

3.2.3 Randomly chose treatment group

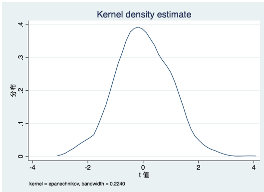
The last placebo test this paper conduct is randomly changing treatment group that the treatment group and the control group were randomly selected for 1000 times for the same DID method. If there are not endogenous problems, the distribution of the coefficient of this repeated experiment should be 0 expectation value and the p value of the coefficient if interest should over 0.1 (it is the same logic for t statistics). And the experiment results are shown in Fig. 3. Form the two distribution, it can be seen that the expectation of the distributions are indeed 0, and the most of the t statistics are relatively small which are strong evidence that there are no endogenous concern.

3.3 PSM method

As mentioned before, when using the DID method for policy evaluation, the endogenous problems are difficult to completely avoid, which puts the validity and accuracy of the results at risk. Therefore, it is necessary to compare the results of the DID strategy with the results of other causal identification strategies. Especially for results estimated from province level data, because of the failure in the robustness test, DID method is inaccurate and inefficient. So, it urgently needs other identification strategies to compare with. There are usually two



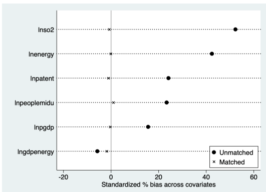
(a) Placebo results of prefecture city data



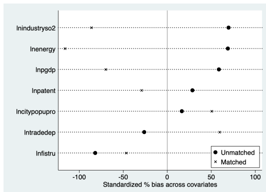
(b) Placebo results of province data

Figure 3: Random year placebo test

methods to solve the problem of inconsistent time trends in the DID method, one is the DDD method and the other is the PSM method. In this part of the robust test, this paper reports the results obtained by the PSM method for comparison.



(a) PSM results of prefecture city data



(b) PSM results of province data

Figure 4: Price Sensitivity Measurement results

Fig. 4 shows the matching effect of the PSM method. It can be seen that the matched treatment group and the control group have similar statistical characteristics, which is an excellent start for further DID method. And in Table 10, the DID estimation result based on the PSM method is reported where DID model remains the same. The signs of both estimators of interesting coefficient remain unchanging. The value of coefficient of city level data is basically the same as the former DID estimation, which is within my expectation because city data is not troubled by inconsistent time trends problem. However, after removing the heterogeneous characteristics, that is, the influence of inconsistent time trends, the results of the province data become very significant, and the value has increased hugely. This result shows that our previous conjectures about the transfer of excess capacity and production factors from the secondary industry to the tertiary industry are relatively robust.

3.4 IV method

Limited by the data, the comparison of DID results with IV methods only became reality on city level data. According to the usual practice, this paper chooses the air circulation rate as the instrumental variable. Its effectiveness has been confirmed in many papers. Therefore, this article omits a series of tests on instrumental variables and only briefly explains. First of all, the air circulation rate can affect the dissipation of pollution,

Table 10: Year placebo test

	Prefecture Cities	Provinces
	(1)	(2)
	erchan	lnindustruco
did	-0.0185^{**}	0.4272^{***}
	(0.0074)	(0.0399)
_cons	-0.3614	8.2319^{***}
	(0.2204)	(1.1112)
controls	*Yes*	*Yes*
City fixed effect	*Yes*	*Yes*
Time fixed effect	*Yes*	*Yes*
N	3468	235
R^2	0.388	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

which means that places with a low air circulation rate are more likely to have more serious pollution. The more polluted areas are more likely to be selected as pilots of the environmental regulation policy of pollution emission trading, which means that air pollution and endogenous variables are highly correlated. Secondly, air pollution as a local meteorological feature is obviously enough exogenous under the framework of policy analysis. Thus, the air circulation rate is still an effective tool variable in this paper. The Eq. 7 and Eq. 8 are the regression model of IV method. And the results of iv method are listed in Table 11.

$$\hat{did}_{it} = \alpha_0 + \beta(iv_{it} \times post_t) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{7}$$

$$erchan_{it} = \alpha_0 + \beta \hat{did}_{it} + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{8}$$

As can be seen from the Table 11, the coefficient of variable of interest remains negative in IV methods, but the absolute value increases extremely, which may indicates that the IV method may have flaws on the issues studied in this paper, because usually the estimate of IV will not exceed ten times that of OLS. However, from the perspective of significance level and sign, the IV method can also further support the robustness of the former results in this paper.

4 Mechanism analysis

This article analyzes how emissions trading affects the industrial structure and overcapacity reduction. The study finds that the mechanism of provincial data and prefecture level city data is similar, so here I only show the city data. First, I promote following assumptions:

- The monopoly of emission rights by large companies has led to a decrease in marketization;
- In order for small enterprises to obtain high-priced pollution rights, the cost increases, and technological innovation declines;
- Due to insufficient technological progress, energy efficiency does not improve;
- Since small companies cannot get the right to discharge pollution, the total sulfur dioxide emissions drop; and

Table 11: IV method

	First stage	Second stage
	(1)	(2)
	did	erchan
ivpost	0.0522***	
	(0.0044)	
didiv		−1.2493***
		(0.2082)
_cons	1.1143**	1.0206***
	(0.5437)	(0.3458)
controls	*Yes*	*Yes*
City fixed effect	*Yes*	*Yes*
Time fixed effect	*Yes*	*Yes*
N	4215	4215
R^2	0.396	0.402

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

- Small firms are eliminated, and excess production capacity and production factors are transferred to the tertiary industry.

To testify these assumptions, Eq. 9 ∼ 12 are conducted. Based on the results listed on Table 12, all the assumptions are proved, which indicates my explanations of the mechanism are correct.

$$erchan_{it} = \alpha_0 + \beta(did_{it} \times lnso2_{it}) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{9}$$

$$erchan_{it} = \alpha_0 + \beta(did_{it} \times lngdpenergy_{it}) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{10}$$

$$erchan_{it} = \alpha_0 + \beta(did_{it} \times lnpatent_{it}) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{11}$$

$$erchan_{it} = \alpha_0 + \beta(did_{it} \times lnmarket_{it}) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{12}$$

5 Heterogeneity analysis

In the heterogeneity analysis part of this article, I mainly focus on whether the effects obtained earlier in this paper are heterogeneous in the east, middle and west of China, and whether they are heterogeneous in the old industrial cities and non-old industrial cities. The estimation model is Eq.13 using relatively different data. The results are displayed in Table 13. The regression results do show the heterogeneity. The results are not significant for cities of the old industrial bases, but the results for cities of the old industrial bases are not significant. The results for cities in eastern and western China are significant, while the results for cities in middle China are not significant. The former result is contrary to the previous study by (Wang and Ming, 1999), who found that. The pollution fee system and the emission reduction subsidy system provide effective incentives for enterprises to invest in pollution control, and their effectiveness is related to the level of enterprise pollution. The more serious the pollution, the stronger the emission reduction efforts generated by the system. I guess the difference here may be caused by the different types of environmental regulations. Traditional environmental

Table 12: Mechanism analysis

	Sulfur Dioxide	Energy efficiency	Innovation	Marketization Degree
	(1)	(2)	(3)	(4)
	erchan	erchan	erchan	erchan
didso2	-0.0018^{***}			
	(0.0006)			
didgdpenergy		-0.0047		
		(0.0064)		
didpatent			-0.0019^{**}	
			(0.0009)	
didmarket				-0.0104^{***}
				(0.0035)
_cons	-0.4118^{*}	-0.4304^{**}	-0.4182^{**}	-0.3978^{*}
	(0.2098)	(0.2077)	(0.2098)	(0.2102)
controls	*Yes*	*Yes*		
City fixed effect	*Yes*	*Yes*		
Time fixed effect	*Yes*	*Yes*		
N	4215	4215	4215	4215
R^2	0.383	0.377	0.379	0.382

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

regulatory policies and environmental regulatory policies that establish a market transaction system may have opposite effects on the results. As for the different results of the regional heterogeneity in China, this paper do not further discuss.

$$erchan_{it} = \alpha_0 + \beta(did_{it} \times post_t) + \theta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{13}$$

Table 13: Mechanism analysis

	Old industrial base or not		East middle west		
	(1)	(2)	(3)	(4)	(5)
	Yes	No	East	West	Middle
did	−0.0040	−0.0269***	−0.0274***	−0.0223**	−0.0096
	(0.0102)	(0.0084)	(0.0080)	(0.0099)	(0.0184)
lnenergy	0.0192**	0.0339***	0.0147	0.0466***	0.0309**
	(0.0094)	(0.0101)	(0.0118)	(0.0101)	(0.0123)
lnso2	−0.0159***	0.0096***	0.0126***	0.0083	−0.0089
	(0.0059)	(0.0037)	(0.0041)	(0.0057)	(0.0064)
lnpgdp	0.0977***	0.0897***	0.1243***	0.0822***	0.0716*
	(0.0199)	(0.0249)	(0.0195)	(0.0181)	(0.0382)
lnpeoplemidu	−0.0591	−0.0157	0.0097	−0.0449	−0.2215**
	(0.0395)	(0.0207)	(0.0176)	(0.0329)	(0.0932)
lnpatent	0.0113*	0.0096*	0.0075	0.0184***	−0.0034
	(0.0059)	(0.0049)	(0.0050)	(0.0062)	(0.0075)
lngdpenergy	−0.0825***	−0.0156	−0.0134	−0.0676***	−0.0259
	(0.0194)	(0.0200)	(0.0214)	(0.0196)	(0.0345)
_cons	0.1342	−0.5034**	−0.8403***	−0.3331	0.9770
	(0.2999)	(0.2319)	(0.1918)	(0.2685)	(0.6125)
N	1425	2790	1710	1500	1005
R^2	0.495	0.357	0.468	0.409	0.419

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6 Conclusion

This paper uses the DID method to study the causal effects of emissions trading on the industrial structure, industry orientation, and heterogeneous capacity reduction through the provincial and prefecture-level panel data from 2003 to 2017. This study finds that emissions trading has no effect on the industrial orientation of green production. Emissions trading can lead to the upgrading of industrial structure, and the flow of resources and production factors from the secondary industry to the tertiary industry. The de-capacity effect of emissions trading mainly affects small manufacturers, and it is the output of eliminated small manufacturers that promote the upgrading of the industrial structure. This paper also analyzes the mechanism of this causal effect. The study finds that the monopoly of pollution emission rights by large manufacturers causes small manufacturers to increase their costs, reduce technological innovation and energy efficiency unchanged, and ultimately makes small manufacturers withdraw from the market. The production factors and resources flow into tertiary Industry. The analysis of heterogeneity shows that this effect is significant for cities without old industrial bases, but insignificant for cities with old industrial bases. This effect is significant in the east and west regions of China, but insignificant in middle China.

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