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# *Carbon Pricing Induces Energy Industries Changes: DID Evidence from China's Carbon Market Pilots*

**Zhengqi Tu**[1,a,*]

*[1] School of Wuhan University, Wuhan, Hubei, China*
*a. zhengqi.tu@whu.edu.cn*
**corresponding author*

***Abstract:*** This paper investigated whether the China carbon emission right trading policy has effects on the energy industry including coal, electricity consumptions. Moreover, this paper focused on energy industries and showed the mechanism that energy consumption is affected due to a reconstruction of energy structure. The paper employed the DID model to compare energy consumption, industries profitability and market sentiment between the ETS regions and ETS related industries. Some novel results are as follows. First, compared with the non-pilot areas. High carbon-based energy consumptions in the ETS areas are significantly reduced. This consumption reduction has come at the cost of production firms' average profitability and net asset to market value. This can result from expectation adjustment of the market investors for the event. Second, because the ETS policy has a gap between the official announcement and market start-up, this paper considered multiple event times and showed that ETS is a multiple-time event, applying usual DID model may lead to confounding results for this. Results show distinct differences on the market reactions and industries reactions for different event times.

***Keywords:*** Carbon Market Pilot, Energy Consumption, Energy Industry, DID

## 1. Introduction

Facing the increasing demand of carbon emission control, Chinese government has introduced many supportive policies. One of the main practices is to introduce market tools in the Carbon Emission Quota, known as the Emission Trading Scheme (ETS). In 2011, the government admitted 7 cities and provinces to prepare the pilot of the carbon emission trading. The pilot started formally in 2013 in the 7 regions, with different target identities and industries. Several different regulations for setting quotas to firms are deployed. More firms were included in succession ever since then, and the target industries are expanded later. In 2021, the national carbon emission trading market was officially launched. It has been considered as a policy to reach the carbon peaking goal and carbon neutrality goals nationwide. In the meantime, it has been considered the determination to regulate the big industry transformation facing the incoming digital and sustainable economy era. While in the process of reducing carbon emission, the energy sector has become increasingly important because of its high emission volume. For instance, all the 7 regions included these industries into primary considerations, hoping to regulate the total emission and boost the carbon trading market's construction. The policy of introducing ETS system has been widely researched in multiple aspects. First, results show that carbon emission marketing significantly reduces the emission of industrial CO2 in all 7 carbon emission trading pilots [1]. The carbon emission permit trade shows higher carbon reduction effects in energy supply side from heterogenous cities [2], but the reduction on emission has not come at the cost of economic development or total factor productivity so far [3].

Do the total consumption of carbon in these energy sector decline because of the carbon trading? Do firms profit from the ETS system? Do the investors believe firms will profit from it? These three questions will be discussed in the remaining part of this paper. Development of carbon trading can reduce some of the high carbon-emission energy seems justified, since regional firms can reduce the total production activities to satisfy the quota, and the industrial emissions are always the largest sources of carbon emission. When introducing carbon emission permit in market, traditional production industries should instantly react and take measures for the upcoming government pressure. The easiest way is to reduce the production activities, but it will reduce the total profit, and finally a lower firm value. Other possible measures include increasing the total R&D expenses to develop more environmentally friendly technologies into every procedure and so on. In fact, Cui et al. found that the pilot study can accelerates innovation in low-carbon technologies [4]. The variety of possible measures lead to difficulties in determine whether firms are losing values or not, and in which part of the firms will have pressure. At the same time, some studies show the heterogeneous effects in province level and local levels for classified governance [5], and shows there exists cross-regional "Carbon Leakage" effect that pilot policy encourages outsourcing of emissions to non-polit regions. The cross-regional effect means firms had taken measures to make use of the imperfect pilot regulations, and the government may have to take the industrial network into consideration for robust results when sourcing the emission. In general, according to Zhao et al., with the increase and of carbon trading market scale, carbon trading market will change from inefficient to weak efficiency on the pricing of carbon permit and then will come to a steady increase of the market [6]. In another aspect, when it comes to the real effects on the firms, the result and conclusions varies. Abrell et al. researched around 2000 EU companies and found out carbon marketing wouldn't bring significant effect on firms' value and profit [7]. Liu used DID to analyze Shenzhen A-share market listed firms' data and find a reduction of current value [8]. Oestreich et al. used empirical data to show carbon marketing can improve the finance conditions and increase the firm's value [9]. Wen had observed the significantly negative long-run asymmetry between the carbon market and the stock market [10].

Since the effect of ETS to firms' value is still unsettled, this article tries to focus its effect to the energy sector's firms and two important milestones. The industries include the thermal, natural gas, and fuel [11]. This paper will research which part is mostly affected. Whether the pilot is regarded as a positive or negative shock to the firms in both aspects, including firms and investors. In general, understanding what roles Carbon Emission Trading Scheme are playing in the transformation and reconstruction of the traditional energy industries, and whether it can bring temporary or long-term effects to certain aspects for those firms helps to better regulate the trading market and improve economic efficiency and benefit. Knowing how did investors react to the new regulations can also help the government to make macroeconomic decisions. By understanding more about the specific effects in certain areas like energy, it can be instructive for future researches and the determination of future policy, while firms and organizations in other industries will also reconsider their plans and make targeted decisions accordingly. Since the environment protection and carbon emission control is a general trend, the research is also beneficial to other countries in facing the development and environmental challenges.

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## 2. Method

### 2.1. Descriptive Statistics

The prime source of regional data is CSMAR database. Listed firm codes and industry classification are collected from CSRC website. For the completeness of data, the data excludes several provinces, and finally 27 provinces are chosen, with 6 provinces in treatment group and 21 provinces as control group. The observation window is 2007-2015, 11 years in total.

Table 1: Descriptive statistics.

| VaeName | Obs. | Mean | SD | Min | Median | Max |
|---|---|---|---|---|---|---|
| Year | 243 | 2011 | 2.587 | 2007 | 2011 | 2015 |
| Lg_Elec | 243 | 7.152 | 0.714 | 4.730 | 7.145 | 8.577 |
| Lg_GDP | 243 | 9.558 | 0.749 | 7.134 | 9.576 | 11.196 |
| Lg_Coal | 243 | 9.241 | 0.863 | 6.026 | 9.313 | 10.689 |
| Lg_Gas | 243 | 3.415 | 1.097 | -0.734 | 3.632 | 5.283 |
| goveEn | 243 | 0.029 | 0.010 | 0.008 | 0.027 | 0.057 |
| Post | 243 | 0.556 | 0.498 | 0 | 1 | 1 |
| ETS | 243 | 0.222 | 0.417 | 0 | 0 | 1 |

Table 1 shows the descriptive statistics of the first regression. $lg\_Elec$ is the regional yearly electricity consumption for all production activities. This variable indicates total usage of electricity. Similarly, $lg\_Coal$ represents the regional yearly coal consumption volume, while $lg\_Gas$ for natural gas consumption. is regional GDP. Higher GDP induces higher energy consumption volume justifies. Considering the unbalance of energy production distribution across provinces, and it is mostly based on the natural endowment, for example the gas storage and production is considerably larger in west part of China than the east. Moreover, taking the volume of yearly environmental expense of government total expense as one of the control variables, which represents the assistance of government in environmental protection.

### 2.2. Baseline Models

Given these variables, the baseline models are as (1):

$$EC_{it} = \beta_0 + \beta_1 Post \times ETS_i + X_{it} + Year_t + Prov_i + \varepsilon_{it} \tag{1}$$

Where the regressions control province level and year level fixed effects by $Prov_i$ and $Year_t$ , respectively. $X_{it}$ are the control variables including $GoveEn$ and $lg\_Gdp$. $EC_{it}$ is a vector of outcome variables, including the consumption volumes of coal, electricity and natural gas. $ETS_i$ is 1 for six pilot regions and zero otherwise. $Post$ is 1 ever since year 2011. Our interest is $\beta_1$, since it indicates how carbon pilot regions react towards the event.

## 3. Results and Discussion

Table 2 presents the pilot's economic effects on energy consumptions from our baseline model. All regressions include the fixed effect in time and regions. In the previous three regressions, control variables are added in sequence. Columns (1) and (2) present the results on the volume of electricity consumption, the interact term is negative and statistically significant at the 1% level. The local GDP level shows high correlations with the electricity consumption level, and significantly positive at 1% level, the magnitude of interact term is smaller due to this powerful explanatory variable, but still is statistically significant at the 1% level. Column (3) is the baseline model, the coefficient of -0.132 indicates that the policy explains about 13.2% decline in the total electricity consumption for those regions in the pilot compared with the control group.

Table 2: Baseline regression results.

| | Electricity consumption | | | Coal | Natural gas |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Post×ETS$_i$ | -0.111** | -0.093** | -0.132** | -0.364** | -0.328* |
| | (-2.175) | (-2.304) | (-2.214) | (-2.204) | (-1.489) |
| lg_Gdp | - | 0.921*** | 0.932*** | 0.912*** | 0.502** |
| | - | (10.685) | (11.750) | (13.921) | (1.865) |
| GoveEn | - | - | 5.000 | 22.390*** | 21.976** |
| | - | - | (1.058) | (5.144) | (1.767) |
| ETS | -0.032 | -0.260*** | -0.223*** | -0.569*** | 0.776** |
| | (-0.102) | (-3.259) | (-2.837) | (-5.417) | (2.143) |
| Post | 0.407*** | -0.153*** | -0.140** | -0.211*** | 0.605*** |
| | (11.134) | (-2.338) | (-2.009) | (-2.661) | (3.167) |
| R-squared | 0.08 | 0.84 | 0.85 | 0.63 | 0.30 |

*Note: *, **, and *** represent statistical significance levels at the 10%, 5%, and 1%, respectively.*

For comparations and robustness, coal and natural gas are included in further regressions. Coal is considered a traditional carbon-costly resources. Since coal-burning power sector, chemical plant, and metal industries are the largest consumers of coal (both fire coal and coking coal), they are the key industries in Carbon Emission Control. While natural gas is considered to be a kind of clean energy for a long time compared with traditional carbon-based energies as coal or fuel.

Not surprisingly, in column (4) and (5), results show the interact term of coal consumption is negative and significant at the 1% level. For natural gas, result show lower significance which is at 10% level, but it is still negative, indicating that natural gas is the least effected energy among them, but due to its carbon emission property, it still shows a weak decline. Results show that local GDP is positively related to the total consumption, which justifies our previous assumption that focusing on consumption end is better.

## 3.1. Mechanism Discussion

So far, the results show that carbon emission right trading can significantly reduce the total regional consumption of coal energy and electricity. The mechanism is that the largest resource of the reduction is from those carbon-costly production industries which are included in the carbon market, forcing them to reconsider the externality cost of carbon emission. In the former researches, the specific start time whether one specific firm is included in the market is uncertain, and the varies of start times and control policies for different industries and different regions may also lead to misunderstanding of results. So, besides the baseline model, a cross-industry research is needed, and the latter part will focus on the power sector industry's effect.

The assumption for cross-industry research is that, due to the effort of ETS pilot market, all the related industries begin to reconsider the carbon emission problem, and are under the pressure of reducing carbon cost no matter whether it is included in the pilot regions. Then, the three power sector industries including electricity, fuel and coal is the treatment group. While the control group, for consistency and comparability, is the major polluting industries identified by China Securities

Regulatory Commission in 2008. The list of major polluting industries includes 78 industries. We exclude those industries that were entered the scheme in the first year. Remaining industries are the control groups. The explained variables $Y_{it}$ is $TobinQ_{it}$ and $netAtM_{it}$. These variables are Tobin Value and Net Asset to Market Value. Higher Tobin Value indicates an underestimate of cooperate value while a larger Net Asset to Market Value indicates shrinkage of net asset value or an increase of market value. Control variables are ROE, ROA, $DebtEquityRatio$ and $AssetLiabilityRatio$. The first two variables indicate the average profitability of the industry, and DebtEquityRatio indicates the leverage ratio. $AssetLiabilityRatio$ shows the average finance burden of the industry. The regression function is as (2).

$$y_{it} = \beta_0 + \beta_1 Post \times Energy_i + Z_{it} + Year_t + Energy_i + \varepsilon_{it} \tag{2}$$

$Energy_i$ takes 1 for above three energy industries and zero otherwise. Post takes 1 after the pilot study, year 2011. The time and industry fixed effect are controlled by $Year_t + Energy_i$. $Z_{it}$ are the control variables.

## 3.2. Industrial Model Results

Table 3 shows the regression results of the TobinQ value, and in all columns, it shows negative interact term $Post \times Energy_i$, which means that the investors will have a negative view of the energy industries, leading to a lower average TobinQ value, and it justifies the rational market that a pressure in the power industries will lead to lower market value, those firms become less profitable due to the control of carbon emission. Other control variables make senses, profitability can increase the TobinQ value, a larger leverage ratio can also bring a positive effect but not as significant as profitability. Lastly, a relatively large debt burden has negative impact on TobinQ value.

Table 3: Industrial regression results.

| | TobinQ | | netAtM | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $Post \times Energy_i$ | -0.593*** | -0.628*** | 0.177*** | 0.167*** |
| | (-3.052) | (-2.956) | (3.408) | (3.051) |
| ROE | 1.354** | - | 0.267 | |
| | (2.350) | - | (1.182) | |
| ROA | 5.493 | 8.917** | -2.908 | -1.999 |
| | | (2.245) | (-1.493) | (-1.569) |
| D/E ratio | 0.145* | 0.059** | 0.029 | 0.006 |
| | (1.669) | (2.118) | (0.936) | (0.392) |
| L/A ratio | -4.678*** | -3.588*** | -0.426 | -0.136 |
| | (-3.861) | (-2.667) | (-0.458) | (-0.194) |
| R-squared | 0.22 | 0.21 | 0.13 | 0.12 |

In (3) and (4), results show a positive impact on the netAtM. Since the market value part is in the numerator for TobinQ but denominator for netAtM. In previous result, a negative impact on market value is justified, so a smaller denominator leads to larger netAtM, which satisfies our assumptions and results in two aspects.

### 3.3. Parallel Trend Tests

One of the vital preconditions for the DID casual inference model is that the policy treatment group should show a parallel trend with others before the event time. Since in previous context, event time is decided as 2011, if a parallel trend is satisfied, then former years' fixed effect should be non-significant until 2011.

The dynamic DID test results are as the Fig. 1 and Fig. 2. In the first parallel trend test, when the policy has not yet been implemented before, the two groups showed parallel trends with zero in confidence intervals. While after the implementation of the ETS pilot, the treatment group shows obviously deviation and downward trend from 2011, and means that the regression is reasonable to get an inference result.

It shows that at first firms successfully adjusted and reduced the electricity consumption strategy immediately, but no so significantly. That may due to the low carbon price in previous years. That is what made firms lack of innovation and crisis consciousness to make changes. While the supply chain is still in normal operation, so as the carbon trading price and trading volume increases, its influence to the enterprise cash flow began to emerge.

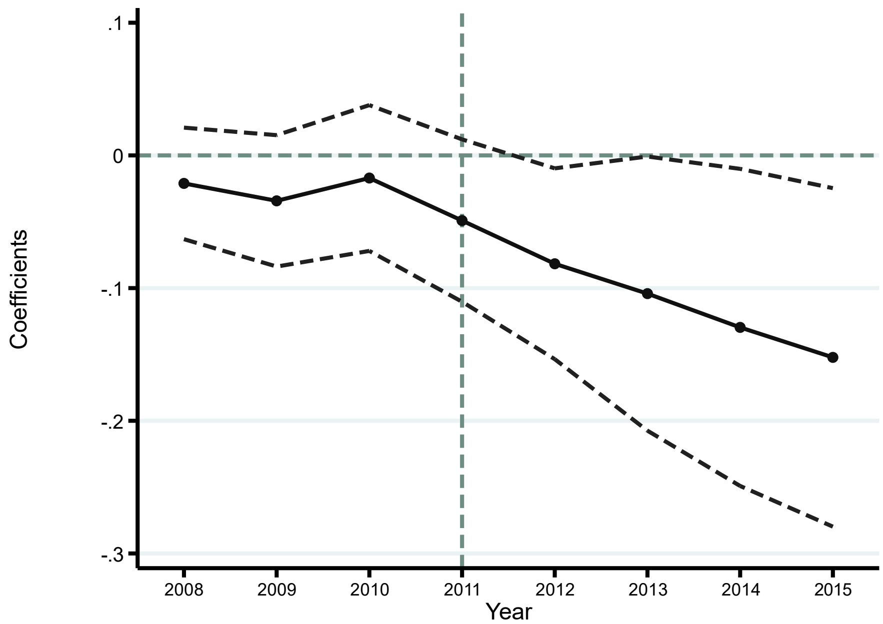


Figure 1: Parallel trend test for electricity consumption.

In Fig. 2, the parallel trend is also satisfied. In 2011 a negative impact of netAtM is estimated. However, the significant deviation is start from 2013, which is the year in which the 7 regions started to run their carbon trading markets. The difference between Fig.1 and Fig.2 on the impact shows that ETS pilot is a complex event with multiple times, making it hard to determine whether to choose 2011 as the shock or 2013 as the shock. For province level researches, these two event years are used in most of previous researches but seldom with explanation. Qi et al. chose 2013 as the policy year to analysis the environmental and economic effects [11], while in their former research, the policy year is 2011 to analysis the innovation increases of the firms. This could be explained as the firm's self-driven innovation will is impacted instantly ever since the announcement of the government, while the economic and environmental effects is since the real introduction of the market, which is from the society aspect. Likely, in Fig.1 results show that with the announcement of the scheme, investors expect the scheme will have a negative impact on target firms especially for traditional energy sectors because of the unexpected carbon emission restrictions. Then as a consequence, firms are undervalued with a significantly lower $TobinQ$ value, and the total consumption of the energy is also significantly reduced, too. However, results in Fig. 2 shows that even after the announcement, the average net asset to market value stays the same until 2013. Since the analysis only focus firms in certain industries, it is plausible to assume they are comparable for steady ratios. While in 2013, a sudden deviation shows that the start of the market rather than the announcement of the scheme leads to an increased ratio, meaning that the market value is relatively lower than before, for some of the firms' value is in the ETS market. This interesting result shows that to this multi-stage event, every milestone should be included or some of the effects may be left out, leading to conflicts in results, which can be important to those analysis in the financial market.

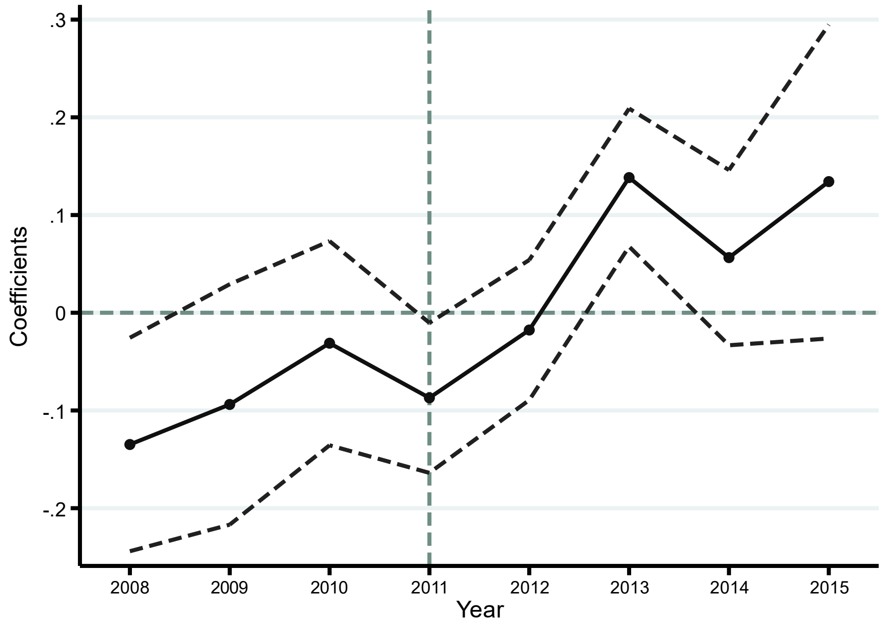


Figure 2: Parallel trend test for net asset to market value.

### 3.4. Counterfactual Test

Another vital precondition is that some confounding event should be excluded for ensuring the event time is plausible. Since 2011 and 2013 is proved to be two important event times as what is shown in Fig. 2, to ensure no other factors in year will affect the result, counterfactual test is deployed, too. The remaining is for the Tobin Value, and the dummy event time has been advanced to 2009 and 2008. The test results were reported in Table 3. It can be seen that both of the two event times have non-significant coefficients in columns (1) and (2), meaning there is no significant difference before the real implement time of ETS on the target variable before. It justifies that before the implementation, no confounding event will affect our estimate. So, an event year before 2011 is excluded. However, in future, the possible confounding year 2011 and 2013 should be taken into consideration seriously.

Table 4: Counterfactual test results.

| | TobinQ | |
|---|---|---|
| | Year2008 | Year2009 |
| $Post \times Energy_i$ | -0.261 | - |
| | (-0.676) | - |
| $Post \times Energy_i$ | - | -0.361 |
| | - | (-1.482) |

## 4. Conclusion

In this article, results show that the pilot study of Carbon Trading System can significantly reduce the total consumption of energy, leading the production activity to use more carbon- neutral resources or try to develop the production method. While among the three energy resources, the greener energy natural gas shows a smaller effect of reduction on the pilot study.

Moreover, results show that this reduction of energy consumption is at a cost of the related production firm's value, as far as concerned, the energy industry shows a decline in $TobinQ$ value, indicating that the profitability of those firms was lower for such a pressure of carbon emission control.

At the same time, a more interesting result is that, the market shows an unanticipated lag of revaluation of these firms, leading to latter's decline of market value among the energy industries. The gap of the two period can indirectly explain that why some previous research results indicating now significant variation on the stock price, since the introducing time and the beginning time have a two-year gap. That is, in the two years, shock in the stock price is deliquated, thus, it cannot be exactly measured quantitatively.

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