

# Will China's low-carbon policy balance emission reduction and economic development? Evidence from two provinces

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## Abstract

**Purpose** – Legislation plays a vital role in solving carbon emissions reduction and climate change issues. China began to implement a low-carbon economic policy in 2010, but the effect of the policy needs to be evaluated. Accordingly, this paper aims to discuss China's low-carbon policy through exploring the following two questions, namely, whether the policy effect reaches the expected goal and whether the policy effects will balance economic development and emission reduction. Then, the paper puts forward suggestions for the improvement of China's low-carbon policy.

**Design/methodology/approach** – This paper is organized around three distinct aspects of policy effect evaluation. This paper uses the synthetic control method to construct a policy effect evaluation model and conducts a quasi-natural experiment. The paper selects annual panel data from 2003 to 2015, which is selected from 33 provinces. A comparative analysis of carbon dioxide emissions, energy consumption and economic development between Hubei Province and Liaoning Province.

**Findings** – The results reveal that the implementation of the low-carbon pilot province policy in 2010 has a significant impact on the emission reduction effect of Liaoning Province, but the impact on the emission reduction effect of Hubei Province is not significant. The carbon emission trading system implemented in 2012 has reduced the emission reductions in Hubei Province and Liaoning Province has achieved better emission reduction effects after the implementation of this policy. After the implementation of the policy, the economic development of Hubei Province has been improved, but it has not brought help to the economic development of Liaoning Province. These findings provide new insights into the use of an emissions trading system for improving economic development and ultimately facilitate the attainment of the broader goal of sustainability.

**Originality/value** – This paper proposes an innovative policy effect evaluation method by considering the status of unit gross domestic product, fixed asset investment in the energy industry, energy consumption,



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emission reduction technology innovation and other evaluation indicators. This paper contributes to broadening current methods of policy effect evaluation in China.

**Keywords** Carbon emissions trading, Climate change law, Low carbon economy, Policy effect evaluation, Synthetic control method

**Paper type** Research paper

#### Notes (Abbreviations)

1. COVID-19: Corona Virus Disease (2019).
2. CSR : Corporate Social Responsibility, while creating profits and assuming legal responsibility for shareholders and employees, enterprises should also take responsibility for consumers, communities and the environment.
3. DID : Differences-in-Differences, a method of policy effect evaluation.
4. ETS : Emissions trading system.
5. MRV : Monitoring, Reporting and Verification. It is the basic requirement of the international community for greenhouse gas emission and emission reduction monitoring.
6. MT : metric ton.
6. SCM : Synthetic control method, a method of assessing the effects of a policy or event.

### 1. Introduction

In the process of coping with global climate change, the Paris agreement has opened a new mode of global emission reduction, and has become the second legally binding document in the field of climate change after the Kyoto protocol. All the Paris agreement signatories would be observing the Intended Nationally Determined Contributions mechanism, using new emission reduction models to combat climate change. China set up pilot projects in low-carbon provinces and cities in 2010. In the process of carrying out low-carbon activities in pilot provinces, the Chinese Government managed the total carbon emission control of all regions, established a regulatory agency and carried out emission reduction actions, such as carbon emission control intensity review and carbon footprint tracking for enterprises. Therefore, the policy of “pilot low-carbon provinces and cities” should be more effective. Since then, China has set up pilot provinces of carbon emission trading in 2012. Based on the pilot policies of low-carbon provinces, carbon emission right is traded as a new type of underlying asset by financial means, to achieve a “win-win” effect of economic development and environmental governance. After unifying the national carbon market in 2017, pilot implementation of the carbon emissions trading policy is “posturing” or can truly achieve emission reduction effect is worth examining. During the implementation of the pilot policy, Hubei led the country in terms of trading volume, liquidity and other indicators and has become the country’s largest carbon market. Liaoning Province has taken the lead in developing the electronic trading system of carbon emission rights, which has promoted the emission reduction effect after the implementation of the policy. Therefore, in the selection of Hubei province and Liaoning province as samples, based on the synthetic control method (SCM), selected provinces annual carbon emissions, energy consumption, such as coal, the original, the producer price index and a comprehensive index to measure low carbon province policy and carbon emissions trading policy on the selected policy differentiation effect of pilot provinces. As the pilot policies of low-carbon provinces and carbon emission trading policies are implemented by national pilot provinces, after the release of carbon emission trading pilot policies, each province has formulated its own carbon emission trading management regulations under the practical

experience of carbon trading. Through the policy implementation effect fitted by the SCM, combined with the low-carbon development strategy among provinces and the provisions of carbon emission trading management regulations, this paper interprets the internal mechanism of policy implementation effect differences, and provides certain reference significance for the development of a low-carbon economy and the promulgation of China's "carbon emission trading management regulations."

## 2. Literature review

As the pilot work of low-carbon provinces and low-carbon cities was carried out, most of the research and analysis was qualitative research. In 2012, the quantitative research on the effect of the policy began to appear after each province successively formulated the carbon emission trading management method. In the aspect of qualitative research on policies of low carbon provinces and carbon market, China's emissions trading system policies have encountered legal and political issues that should be solved so that a national policy could help to mitigate emissions (Baark, 2019). Because of the contradictions and shortcomings in the existing mechanism for trading permits for CO<sub>2</sub> emissions, the policy does not to achieve the results on reducing emissions recorded on environmental regulation (Svetlana and Anna, 2020). The policy tool of low-carbon development is the theoretical support for the realization of macroeconomic goals. The carbon market policy to sustained and effective role in the enterprise, and be able to truly achieve reductions should be set from the legal system, framework arrangement, institutions and regulation policy of four basic elements, to be able to pilot system will join each other with the carbon market development, shall guarantee the heterogeneity of policymaking and implementation effect, especially for the rules of carbon trading policy main body part of the pilot provinces should be "complement each other" (Pang *et al.*, 2014). Some scholars analyzed the sustainability of low-carbon city policies using the multi-standard decision-making method, and the research results provided suggestions for Bangkok's energy and low-carbon economic development, and emphasized the steps needed to promote a sustainable low-carbon society (Phdungsilp, 2010).

In terms of the research on the implementation effect of pilot policies and carbon trading policies in low-carbon provinces based on quantitative methods, some scholars proposed that the influencing factors of carbon emissions include the effects of gross domestic product (GDP), population, energy consumption per unit production value and unit energy consumption emission factor, and proposed the calculation formula (Kaya and Keiichi, 1997). There is a synergy between economic growth, CO<sub>2</sub> emissions, urbanization and energy consumption. Public policy design needs to make concerted efforts to ensure the reduction of urbanization level, and the sustainability of urbanization without harming economic growth. Policies should be formulated to ensure the reduction of CO<sub>2</sub> emissions to achieve a high-quality environment (Odugbesan and Rjoub, 2020). Some scholars evaluated the effect of the implementation of pilot policies in China's low-carbon provinces on the total carbon emissions, and proposed that there was no significant difference in the total carbon emissions between pilot provinces and non-pilot provinces before and after the implementation of the policies, Chongqing and Shaanxi provinces were greatly affected by the policies (Lu, 2017). Reduce carbon emission at the data center is an important method to reduce the energy consumption and increase the resource availability (Gogineni and Gunasekhar, 2020). In addition, some studies suggest that natural resources and economic growth have a positive impact on CO<sub>2</sub> emissions, while renewable energy has a negative impact on CO<sub>2</sub> emissions (Aeknarajindawat *et al.*, 2020). Since 2017, after the carbon market, which is only aimed at the unification of the whole country electric power industry, Chinese scholars have made a comparative analysis on the power consumption intensity of low-

carbon provinces before and after the implementation of the pilot policy. The results show that the low-carbon pilot provinces will consume less electricity than non-provincial capital cities, and the policy effect is obvious, but the effect on non-provincial capital cities is not obvious (Li, 2018). The carbon market of Hubei province is at the weak-type effective level through first-order regression analysis, while Liaoning province is at the weak-type invalid level, but the effective level gradually increases with the increase of carbon quota, which indirectly proves the effectiveness of carbon trading policies of Hubei province and Liaoning province (Zhao and Wang, 2018). Under the condition of complete information, the implementation cost of the total control policy is lower than that of the carbon emission trading policy, but the effect is opposite after the policy is implemented (Malik, 1992). The regional carbon trading policies had positive effects on local carbon emissions, and proposed to establish a cap-and-trade system among local governments (Torres and Pinho, 2011).

Most of the research results focus on the integrity of the seven pilot provinces and cities, without detailed consideration and analysis of individual provinces and cities, so the heterogeneity research is relatively weak. At the same time, the qualitative comparison method can avoid the disadvantages of multiple policy interference and make subjective and objective evaluation results for policy effect and policy improvement (Liu *et al.*, 2013). Therefore, based on the analysis of SCM, with the help of policy effect evaluation theoretical framework, comprehensive indicators such as annual carbon emissions, coal, crude oil, industrial producer price index and other comprehensive indicators are selected to consider the policy differentiation effect of low-carbon provincial policies and carbon emission trading policies. This paper analyzes the advantages of provinces with better policy effect and improves the content of national carbon emission trading management regulations, to better promote and guarantee the development of the low-carbon economy. The research framework can be seen in Figure 1.

### 3. Materials and methods

Pilot policies of low-carbon provinces and carbon emission right trading policies are experimental measures of China to implement a unified carbon market and promote the development of the green economy. The after-the-fact evaluation of pilot policies and the optimal combination of policy effects are the key contents of legal empirical research. Many scholars use the differences-in-differences (DID) method, propensity matching score and other methods to evaluate the effect before and after the implementation of the policy (Grafova *et al.*, 2014). However, the premise of did method is that the treatment group and the control group have a similar trend. In the implementation process of pilot policies and carbon emission trading policies in low-carbon provinces, the economic development, emission control and energy consumption degree of different regions are obviously different. In the case of no low-carbon pilot provinces, the mutual emission reduction methods may not be similar or the same. Therefore, it is not reasonable and effective to evaluate the implementation effect of carbon emission reduction economic policies by using the multiple difference method. Abadie and Gardeazabal proposed the SCM to overcome the limitations caused by the DID method (Abadie and Gardeazabal, 2003). According to the different objects in the control group, the weights are given, respectively, and a composite control group is created by the weighted average method. The purpose is to achieve a high degree of coincidence between the behavior of the composite control group and the intervention group before the policy intervention, so that if the intervention group after the event is not intervened by the policy, its behavior can still maintain a more consistent feature with the composite control group that is the composite control group. The ex post outcome of the control group can be used as the object counterfactual result of the intervention group, then

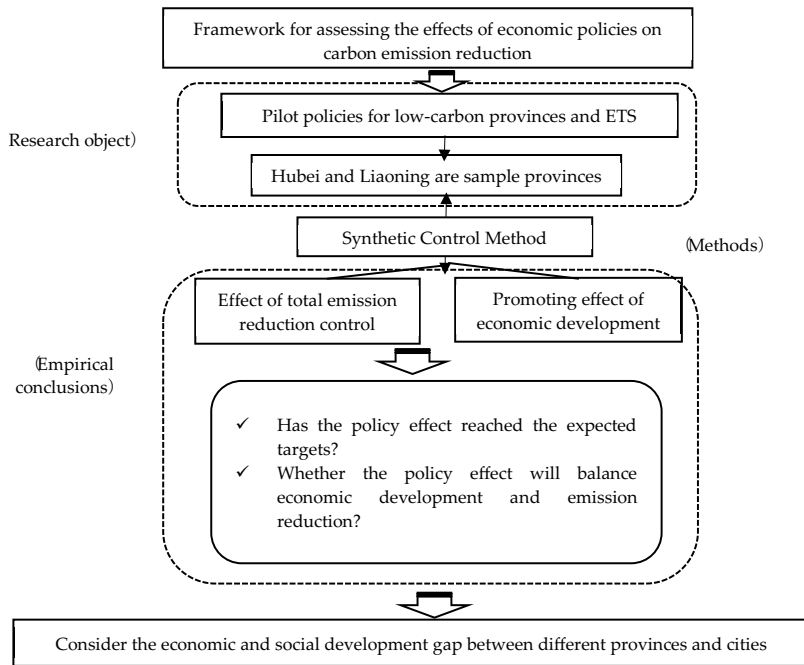


Figure 1. Research framework

the difference between the intervention group and the composite control group is the influence of policy intervention (Abadie *et al.*, 2012). The main path of using SCM to research carbon emission reduction policy is: select the control group of specific index synthesis and treatment group through the synthesis method, and evaluate and analyze whether the emission reduction effect can be achieved by comparing the difference between the real province and the synthetic Province in the low-carbon Province pilot policy and carbon emission trading policy, respectively.

### 3.1 Model specification

The basic assumption is that if there are  $N + 1$  regions, region 1 (take Hubei province as an example) is subject to policy intervention at the later stage of  $T_0$ , the sample interval is  $[1, T]$  ( $1 \leq T_0 \leq T$ ) and other  $N$  regions are not subject to policy intervention, as the control group that is other regions in Hubei province and Liaoning province are excluded. If the low-carbon province policy and carbon emission trading policy have already started to have an impact before they are implemented, then  $T_0$  is the cut-off point when the policy starts to have an effect (Eren and Ozbeklik, 2016). According to the counterfactual analysis framework,  $i$  the period  $t$  ( $t = 1, [..], T$ ) is not included in the index observation values of the low-carbon pilot province and the carbon emission trading pilot province, making the index observation values of the province  $I$  after the intervention of two low-carbon policies in period  $T$ . The model can be constructed as equation (1):

$$Y_{it} = Y_{it}^N + \alpha_{it} D_{it} \tag{1}$$

$D_{it}$  refers to the state of intervention received by province  $I$  during period  $t$ , which is a dummy variable, for all  $i$ , when  $t \leq T_0$  is less than or equal to  $T_0$ . The point of concern is that when  $t > T_0$ , that is the processing effect in the research analysis. As  $t > T_0$  is an appreciable indicator, but it is not appreciable because it is a counterfactual indicator, the estimation of should be estimated first. The factor model constructed by Abadie *et al.* was used for estimation (Abadie *et al.*, 2010).

$$Y_{it}^N = \delta_t + \theta_t Z_i + \lambda_t \mu_i + \varepsilon_{it} \quad (2)$$

In the equation (2),  $\delta_t$  is the common factor, which has the same effect on all object provinces and  $Z_i$  is a set of observable covariate vectors (which may be confounding factors) unaffected by the policy.  $\lambda_t \mu_i$  is the product of individual fixed effect  $\mu_i$  and time fixed effect  $\lambda_t$  and  $\varepsilon_{it}$  is the random disturbance term. To estimate that when  $t > T_0$ , if there is no index  $Y_{it}^N$  affected by the carbon emission reduction policy in the pilot provinces, the weight vector of synthetic control  $W = (w_2, \dots, w_{N+1})$  and it is constructed to meet the requirement for any  $n$ ,  $w_n \geq 0$  and  $w_2 + \dots + w_{n+1} = 1$ . The value of each given weight vector  $W$  represents a weighted average of all provinces in the potential control group that is a feasible synthetic control combination of pilot provinces. The result variable of the synthetic control region can be written as equation (3):

$$\sum_{j=2}^{N+1} w_j Y_{jt} = \delta_t + \theta_t \sum_{j=2}^{N+1} w_j Z_j + \lambda_t \sum_{j=2}^{N+1} w_j \mu_j + \sum_{j=2}^{N+1} \varepsilon_{jt} \quad (3)$$

Suppose there is a weight vector  $W^* = (W^* 2, [\dots] W^* J + 1)'$ , equation (4) can be obtained:

$$\begin{aligned} \sum_{j=2}^{N+1} w_j^* Y_{j1} &= Y_{I1}, \quad \sum_{j=2}^{N+1} w_j^* Y_{j2} = Y_{I2}, \quad \dots, \\ \sum_{j=2}^{N+1} w_j^* Y_{jT} &= Y_{IT_0}, \quad \sum_{j=2}^{N+1} w_j^* Z_j = Z_I \end{aligned} \quad (4)$$

Abadie *et al.* demonstrates in the appendix  $\sum_{t=1}^{T_0} \lambda_t \lambda_t'$  was non-singular, there is equation (5):

$$Y_{it}^N - \sum_{j=2}^{N+1} w_j^* Y_{jt} = \sum_{j=2}^{N+1} w_j^* \sum_{s=1}^{T_0} \lambda_t \left( \sum_{n=1}^{T_0} \lambda_n' \lambda_n \right)^{-1} \lambda_s' (\varepsilon_{js} - \varepsilon_{1s}) - \sum_{j=2}^{N+1} w_j^* (\varepsilon_{jt} - \varepsilon_{1t}) \quad (5)$$

It can be found that, when the carbon emission reduction policy can be effective for a long time ( $T_0 \rightarrow \infty$ ), equation (4) will approach to 0. Then, within the time limit  $t \in (T_0, T]$  of the policy action, that allows  $\sum_{j=2}^{N+1} w_j^* Y_{jt}$  to be an unbiased estimate of  $Y_{it}^N$ . Thus, the processing effect estimator of the carbon emission reduction policy can be obtained as follows equation (6):

$$\hat{\alpha}_{it} = Y_{it} - \sum_{j=2}^{N+1} w_j^* Y_{jt} \quad (6)$$

The estimator  $W^*$  of the treatment effect can only be obtained by finding  $\hat{\alpha}_{it}$  that meets the conditions. In other words, the eigenvectors of the first province should be in the convex combination of the eigenvectors of other provinces, but in fact, it is not guaranteed that the solution of the equation set can be obtained exactly according to the existing data. At this time, the approximate solution can be used to determine. So, by minimizing the distance function between  $X_1$  and  $X_0$ ,  $\|X_1 - X_0W\|_v = \sqrt{(X_1 - X_0W)' V(X_1 - X_0W)}$  determine  $W^*$ . According to the distance function proposed by Abadie *et al.*, which  $v$  is a symmetric semi-positive definite matrix, the choice of  $v$  will affect the mean square error of the estimated value.

### 3.2 Variable setting and data selection

**3.1.1 Policy background.** In the research on whether the effect of carbon emission reduction policies in low-carbon pilot provinces is ideal, it is mainly based on the pilot policies of low-carbon provinces and carbon emission trading policies two policy files are, namely, “low-carbon provinces and low-carbon urban pilot work plan” and “carbon emissions trading pilot work plan.” Hubei province and Liaoning province are selected as the main research objects. The main reason is that Hubei province leads the country in trading volume, liquidity and other indicators and has become the largest carbon market in China (Yan, 2014). Compared with Beijing, Shanghai and other cities, the economic growth, industrial structure and energy structure of Hubei province are very representative. The regional differences in Hubei province are close to the national average. Liaoning Province is the first province to adopt the electronic trading system, and the transaction form has certain representativeness. The composition is set to remove other provinces (excluding Tibet) from the pilot provinces.

**3.1.2 Data selection and variable setting.** The data source is the website of the National Bureau of Statistics (year: 2003–2015), this paper evaluates the emission reduction effect of Liaoning and Hubei from the aspects of carbon dioxide emissions, energy consumption and economic development. By comparing the difference between the actual value of carbon emissions in each region before and after the implementation of the pilot policy of low-carbon provinces and the “counterfactual” estimate of the composite control area, the implementation effect of carbon emission reduction policy is examined (Su and Hu, 2015). The reference coefficients of various energy carbon emissions are shown in Table 1. The carbon emission estimation formula is as follows equation (7):

$$TC = \sum_{q=1}^n E_q \times S_q \times F_q \quad (7)$$

$TC$  is the total carbon emission,  $E_q$  is the consumption of category  $q$  energy, including: raw coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil and oilfield natural gas.  $S_q$  is the conversion coefficient of standard coal corresponding to various energy sources and  $F_q$  is the carbon emission coefficient corresponding to various energy sources (Xibao *et al.*, 2015). The total annual carbon emission of each province from 2003 to 2015 can be calculated. The method of Kaya Yoyichi was used to select the variables of the synthetic provinces (Kaya, 1989). It is mainly composed of the following:

**Table 1.**  
Table of carbon  
emission of various  
energy

Energy	Average post calorific value (kj/kg)	Discount standard coal coefficient (kgce/kg)	Carbon per unit calorific value (ton of carbon/TJ)	Carbon oxidation rate	CO <sub>2</sub> emission coefficient (kg-CO <sub>2</sub> /kg)
Raw coal	20,908	0.7143	26.37	0.94	1.9003
Coke	28,435	0.9714	29.5	0.93	2.8604
Crude oil	41,816	1.4286	20.1	0.98	3.0202
Fuel oil	41,816	1.4286	21.1	0.98	3.1705
Gasoline	43,070	1.4714	18.9	0.98	2.9251
Kerosene	43,070	1.4714	19.5	0.98	3.0179
Diesel	42,652	1.4571	20.2	0.98	3.0959
LPG	50,179	1.7143	17.2	0.98	3.1013
Refinery dry gas	46,055	1.5714	18.2	0.98	3.0119
Natural gas	38,931 kJ/m <sup>3</sup>	1.3300 kgce/m <sup>3</sup>	15.3	0.99	2.1622 kg-CO <sub>2</sub> /m <sup>3</sup>

Source: IPCC, (2006)

- Unit GDP, which reflects the level of economic development of the province.
- The total population at the end of the year, reflecting the size of the city.
- The year-end loan balance of financial institutions (in both local and foreign currencies) reflects the financial development level of the province.
- Fixed asset investment in the energy industry reflects the degree of industrialization of this province.
- The number of foreign-funded enterprises and the total amount of investment by foreign-funded enterprises reflect the degree of internationalization of the province.
- The number of ordinary institutions of higher learning and the total number of students, which reflect the education level of the province.
- Energy consumption (including coal and crude oil) reflects the scale and level of energy consumption of provinces.
- The number of domestic applications for accepting intellectual property rights reflects the development of science and technology in this province.

The above data sources are the website of the national bureau of statistics, China statistical yearbook and China energy statistical yearbook.

#### 4. Results

The original intention of the policymaking of the low-carbon economy is to realize the coordination between carbon emission reduction and economic development. Through the carbon emission right trading system, the carbon emission in the region can be reduced and financial innovation and technological innovation can be promoted, to finally achieve economic development (Arshad *et al.*, 2020). Therefore, from the perspective of the impact of the policy effect on the region. First, this paper analyzes whether the economic policy of carbon emission reduction can effectively control the regional carbon emissions. Through the SCM, the weight of non-pilot provinces implementing the carbon emission reduction policy is assigned to the pilot provinces, and the results are shown in Table 2 below.



**Table 2.**  
Non-pilot provinces  
are given weight in  
pilot provinces

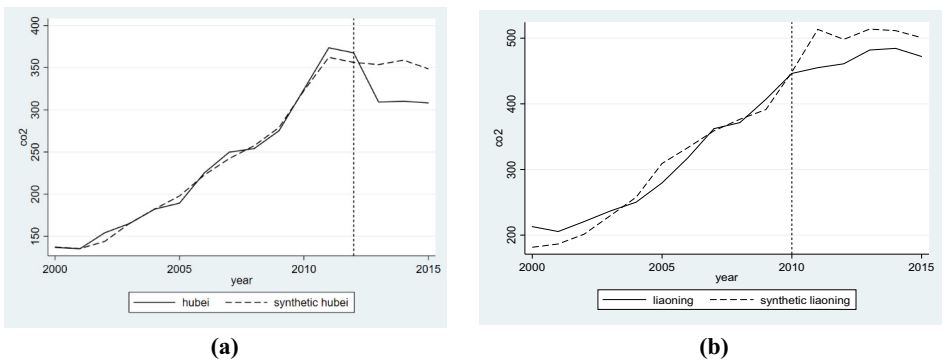
Province	Hubei	Liaoning	Province	Hubei	Liaoning
Anhui	0	0	Jiangxi	0	0
Chongqing	0	0	Jilin	0	0
Fujian	0	0	Liaoning	0.171	0
Gansu	0	0	Inner Mongolia	0	0
Guangxi	0	0	Ningxia	0	0
Guizhou	0	0	Qinghai	0	0
Hainan	0	0	Shandong	0	0
Hebei	0	0.502	Shanxi	0	0
Heilongjiang	0.401	0.498	Sichuan	0.367	0
Henan	0	0	Xinjiang	0	0
Hunan	0	0	Yunnan	0	0
Jiangsu	0.061	0	Zhejiang	0	0

4.1 Impact of policies on carbon emissions and economic development

4.1.1 Impact of policies on carbon emissions. The fitting situation and change trend of the real value of total carbon emission in Hubei and Liaoning province from 2003 to 2015 and the SCM are shown in Figure 2.

Among them, the vertical dotted line indicates that the pilot policies and carbon emission trading policies of low-carbon provinces were implemented in 2010 and 2012. The total carbon emissions between Hubei Province and the synthetic Hubei Province are very close when the pilot policies of low-carbon provinces are implemented in 2010, and the fitting degree is good. That is to say, the implementation effect of the pilot policies of low-carbon provinces in 2010 in Hubei Province is not obvious. However, Liaoning Province has begun to have obvious changes. After the implementation of the carbon emission trading policy after 2012, the synthetic Hubei Province is significantly higher than the real Hubei Province, which means that the policy effect has reached the expected, and the carbon emission reduction has changed significantly. Compared with this, Liaoning Province has reduced the total carbon emissions, as the implementation of the low-carbon provincial pilot policy in 2010, indicating that the policy effect has begun to play a role, and the effect after 2012 is more significant. On this basis, to have a clearer understanding of the impact of carbon emission trading policy on the total carbon emission control of Hubei and Liaoning Province, the real value and composite value of carbon emissions in Hubei Province and

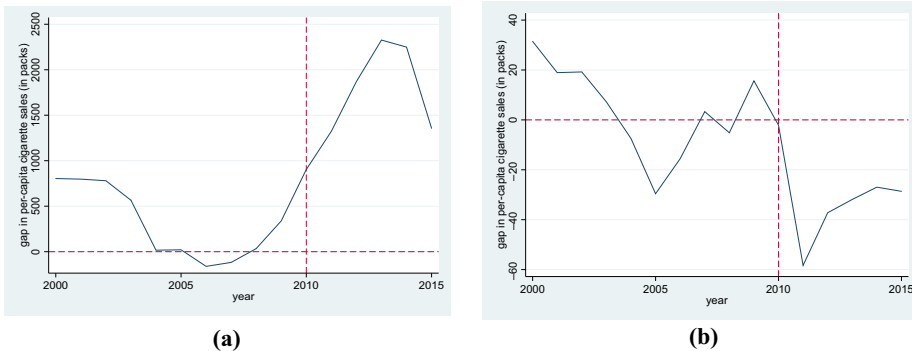
**Figure 2.**  
Comparison of total carbon emission of Hubei province (a) and Liaoning province (b) with that of synthetic Hubei province (a) and Liaoning province (b)



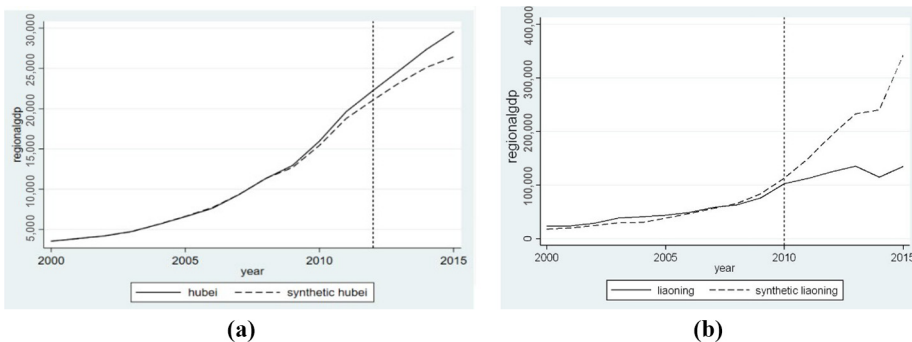
Liaoning Province are analyzed in the empirical study, and the change track of treatment effect under time series is analyzed, as shown in Figure 3.

It can be found from Figure 3 that: in 2010, when the pilot policy of low-carbon provinces was implemented, Hubei Province had a small fluctuation, while Liaoning Province had begun to have a large fluctuation. However, after 2012 (that is, after the implementation of the carbon emission trading policy), the change of the treatment effect has increased sharply and it is a “negative treatment effect,” that is, the emission reduction has increased significantly. According to the contents reflected in Figures 3, it can be concluded that: the pilot policy of low-carbon provinces in 2010 did not have a substantial policy effect on the total carbon emissions of Hubei Province, but Liaoning Province has begun to take effect. After the carbon emission trading policy in 2012, Hubei Province has greatly reduced the total carbon emissions, and the carbon emission reduction effect of Liaoning Province is more significant on the original level in 2010.

4.1.2 *Impact of policies on economic development.* The implementation of carbon emission reduction economic policy is to promote economic development while controlling the total amount of carbon emission reduction. The policy effect of emission reduction has been verified before and after the implementation of the policy in the pilot provinces. To observe whether the economic development level in the region will show an upward trend after the increase of emission reduction, the SCM is continued to be used for analysis and the fitting situation and change trend can be seen. It is shown in Figure 4.



**Figure 3.** Comparison of the total carbon emission gap between Hubei Province (a), Liaoning Province (b) and synthetic Hubei Province and Liaoning Province



**Figure 4.** Comparison of unit GDP between the two provinces

It can be seen from [Figure 4](#) that the fitting degree of Hubei Province before 2010 is good. After the implementation of the low-carbon provincial pilot policy, the real value of unit GDP in the region is higher than the composite value. After 2012, it is still in a rising state and the gap is gradually increasing. This shows that after the implementation of the economic policy of carbon emission reduction, the level of unit GDP in the region increases, indicating the implementation of the economic policy of carbon emission reduction. During the construction process, the local economic development level was promoted. However, the effect of policy implementation in Liaoning Province on the development trend of regional GDP is not good, and the composite value is higher than the real value. This shows that the policy has not brought help to the economic development of Liaoning Province.

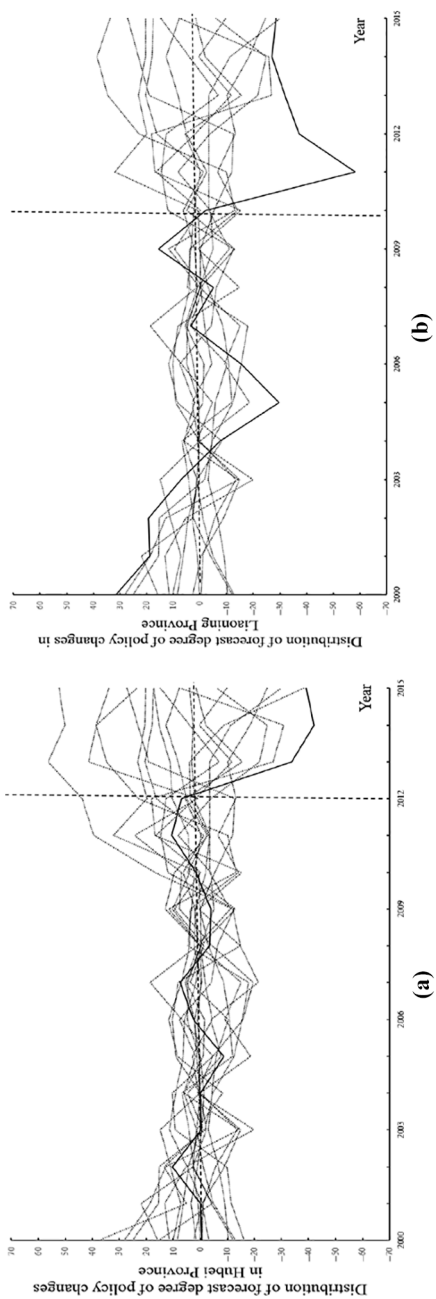
*4.1.3 Robustness test.* To test the robustness of the above composite control estimation results, a placebo test was conducted in potential control group areas ([Abadie et al., 2015](#); [Zhao, 2017](#)). The idea of the placebo test is to treat potential control samples as hypothetical processing areas, and treat Hubei and Liaoning provinces as control areas, and then use the SCM to estimate the policy effect, also known as “placebo effect.” Through this series of “placebo tests,” it can get the distribution of placebo effect, and compare the treatment effect of Liaoning Province and Hubei Province. The results are shown in [Figure 5](#).

In [Figures 5\(a\) and \(b\)](#), the solid line indicates the treatment effects of Hubei Province and Liaoning Province (Hubei Province, Liaoning Province and Hubei Province, Liaoning Province and total CO<sub>2</sub> emissions) and the dotted line indicates the other 18 control group provinces. Placebo effect. Obviously, compared with other provinces, the (negative) treatment effect of Hubei Province and Liaoning Province is particularly large. If the low-carbon province pilot policy and the carbon emission trading policy have no effect, then in these 18 cities, the probability of the largest treatment effect in Hubei and Liaoning provinces is only  $1/18 = 0.05$ , from the perspective of traditional statistics. See, this also shows that the low-carbon province pilot policy and the carbon emissions trading policy effect are highly significant at the 5% significance level.

#### *4.1.4 Evaluation and analysis of policy effect in two provinces*

*4.1.4.1 Evaluation on the effect of regional low-carbon policy in China* The main goal of China’s low-carbon policies and regulations is to control carbon dioxide emissions and form a sustainable society ([Fawcett, 2010](#)). After the implementation of regional low-carbon policies, Hubei and Liaoning have produced very good emission reduction effects, which proves that the regional low-carbon policies can effectively reduce energy consumption and promote the development and use of low-carbon technologies. In the case of policy superposition, the effect of policy implementation gradually appears. Liaoning Province has formulated the notice of the people’s government of Liaoning Province on printing and distributing the work plan for greenhouse gas emission control, established the carbon emission report and verification, quota allocation management and trading system, and established an effective regulatory mechanism. To achieve the policy effect, the government should establish an open and transparent carbon emission trading policy and system, and form a market environment of overall supervision, standardization and order, openness and transparency. The policy effect depends on the dominant position of the carbon trading market, and the cost of emission reduction can be reduced by giving full play to the driving role of the market mechanism ([Steven and Jos, 2003](#)).

*4.1.4.2 Effect evaluation of regional carbon emission trading policy in China* Based on the low-carbon policy, the carbon emission trading policy has achieved an obvious emission reduction effect. In Hubei Province and Liaoning Province, enterprises are facing greater pressure to reduce emissions. The shortage of free quota in carbon emission trading will significantly improve the subjective understanding of enterprises on emission reduction



**Figure 5.** Distribution of policy changes in Hubei (a), Liaoning (b) and other provinces

pressure. Different from before the implementation of the policy, after the implementation of the policy, most enterprises have set their own emission control targets or strategies, enterprises in Hubei Province are more inclined to achieve emission reduction through technological innovation. However, Liaoning Province is more inclined to adopt government intervention measures to reduce market uncertainty and increase investment demand for emission reduction through the transformation of the electronic trading system. The main reason for enterprises to carry out quota trading and storage is to meet the requirements, and the proportion of carbon assets operation is very low. To improve the effect of the policy, the government should turn the policy into law to ensure that the enterprise can perform the agreement according to the law (Streck, 2012). At the same time, due to the operability of monitoring, reporting and verification rules, the design of quota allocation method should ensure a reasonable quota shortage level to promote the overall emission reduction, the quota allocation method based on actual production should be used to effectively promote the application of emission reduction technology, and regulatory measures should be set up to ensure a reasonable and stable carbon price, but the transparency of policies should be improved to avoid increasing uncertainty (Deng et al., 2018).

4.1.4.3 The way of policy effect balancing carbon emission reduction and economic development In terms of emission reduction control, before and after the implementation of the low-carbon policy, the emission reduction effect of Hubei Province and Liaoning Province is relatively obvious. By 2020, the emission reduction amount of Hubei Province is even greater, reaching 40.7 MT, a year-on-year decrease of 44.4%. Liaoning Province also controls the energy consumption increment within 35.5 million tons of standard coal. The empirical results obtained by the comparative analysis method of “control object experimental object” in process control method are shown in Table 3 below (A<sub>1</sub> represents before the implementation of the policy and A<sub>2</sub> represents after the implementation of the policy). Overall, the effect of the economic policy of carbon emission reduction has reduced the total carbon emissions of the two pilot provinces, which has played a very good role. From the promotion of economic development, the economic development of Hubei Province has been significantly improved after the implementation of the carbon emission reduction

Year	Hubei Province			Liaoning Province		
	A <sub>1</sub> (before)	A <sub>2</sub> (after)	Policy effect index	A <sub>1</sub> (before)	A <sub>2</sub> (after)	Policy effect index
<i>Evaluation index of carbon emission reduction effect</i>						
2009	279.07	275.20	3.872	213.00	181.52	31.48
2010	322.78	324.30	-1.52	205.50	186.56	18.94
2011	362.26	373.60	-11.34	220.70	201.48	19.22
2012	356.26	367.60	-11.34	236.70	229.50	7.20
2013	353.67	309.20	44.46	250.20	257.67	-7.47
2014	358.99	310.20	48.79	279.60	309.20	-29.60
2015	348.61	308.20	40.39	317.90	333.47	-15.57
<i>Evaluation index of economic development</i>						
2009	12,961.10	12,274.61	686.49	4,669.06	3,864.88	804.18
2010	15,967.60	14,806.28	1,161.32	5,033.08	4,235.48	797.60
2011	19,632.30	17,954.06	1,678.24	5,458.22	4,678.32	779.90
2012	22,250.40	20,053.18	2,197.22	6,002.54	5,436.59	565.95
2013	24,791.80	22,141.32	2,650.48	6,672.00	6,655.63	16.37
2014	27,379.20	23,932.69	3,446.51	8,047.26	8,026.61	20.65
2015	29,550.20	25,334.16	4,216.04	9,304.52	9,465.81	-161.29

**Table 3.**  
Empirical results of the analysis of policy effects using process comparison

policy. Liaoning Province is a resource exhausted Province, and its economic development is backward. Therefore, after the policy is extended to the national level, resource exhausted cities will inevitably have such problems.

Meanwhile, COVID-19 novel coronavirus pneumonia worldwide has undoubtedly seriously disrupted the 2020 sustainable development agenda, but it has not cut the importance and urgency of reducing the problem of carbon economy development. Hubei Province should give priority to low-carbon economy growth after the COVID-19, to avoid the hidden dangers of long-term development caused by the recovery plan after the epidemic. Liaoning Province should promote low-carbon development and economic development in the post epidemic from the overall perspective of the unified carbon market, first, to limit the industry threshold included in emission reduction is to plan the emission reduction scheme from the perspective of industry (Liu and Hui, 2011). By establishing the total emission target for enterprises, most large emission control enterprises can be forced to fulfill their CSR (Corbett *et al.*, 2018), adopt low-carbon green production mode in production and operation, accelerate the generation of green supply chain, and accumulate. It will drive the low-carbon behavior mode of upstream and downstream enterprises, and ultimately promote the development of green and low-carbon economy (Song *et al.*, 2018).

## 5. Conclusions and policy implications

The above analysis shows that the carbon emission trading system is necessary and feasible for improving the ecological environment and improving resource utilization efficiency, and the reform of the carbon emission trading system should avoid the softening phenomenon brought by the traditional direct command-and-control environmental governance system (Liu *et al.*, 2013). By comparing the carbon emission reduction and economic development of Hubei Province and Liaoning Province before and after the implementation of low-carbon policy, the conclusion of this paper is that China's regional low-carbon policy can reduce the total carbon emissions, control energy consumption and promote low-carbon technological innovation. However, low carbon policy has some limitations in promoting regional economic development. The policy does not help the economic development of resource exhausted cities. Suggestions for improving the policy system can be started from the following aspects:

First, it is necessary to define the overall goals and phased targets of carbon emission trading and promote the implementation of carbon emission trading in an orderly and step-by-step manner under the overall framework (Song and Li, 2015). Attention should be paid to the effectiveness of carbon emission trading so that carbon emission trading can be observed and effectively implemented. The economic entities should recognize the importance of carbon emission trading from the perspective of improving their own ecological welfare, and it can actively abide by the corresponding rules. Second, the basic content of carbon emission trading should be defined and the operating mechanism, incentive mechanism and constraint mechanism of carbon emission trading should be scientifically and reasonably constructed. Market mechanisms should play a decisive role in the process of carbon emission trading to avoid strong governments or interest groups becoming the root cause of softening carbon emission trading (Chen and Wang, 2013). Finally, it is necessary to establish the concept of incentive compatibility to accurately define the stakeholders of carbon emission trading and promote the full cooperation of all stakeholders with the goal of promoting each other's interests (Song *et al.*, 2020). In this way, the economic entities gradually abandon the idea of using or circumventing the system, and keeps making the rigid characteristics of the system binding on the economic subject, to avoid the low efficiency caused by the softened system for carbon emission trading.

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### Further reading

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