Evaluation on the emission reduction benefits of China's Carbon Trading Pilot

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Abstract. Evaluation on the emission reduction effect of the carbon trading pilot is very important for China's energy conservation and emission reduction. This paper uses the generalized linear model to evaluate the emission reduction effects of China's carbon trading pilot. The results show that existing Carbon Trading Pilots slow down the relative increase of carbon emissions in the pilot areas, and their emission reduction effect is relatively obvious before and after the establishment of the carbon trading pilots from 2010 to 2012. However, as time goes by, the emission reduction effects in the adjacent period become weak. Therefore, it is necessary to implement the national carbon market as soon as possible to promote the energy saving and emission reduction of national province scale.

1. Introduction
In order to cope with climate change and mitigate carbon emissions, the government can promote emission reduction by using carbon trading market mechanisms [1]. In 2011, China's seven carbon trading pilots have all started and completed the transaction. At the end of 2017, the national unified carbon emission market was launched. However, whether carbon trading has really played a role in promoting emission reduction is still very lack of research [2-4]. Therefore, we use the generalized linear model to evaluate the emission reduction effect of China's carbon trading pilot, aiming to provide data support and theoretical analysis for China to further promote the carbon trading market and enhance the emission reduction effect through carbon trading.

The carbon emissions data of provincial fossil fuels in the paper are calculated based on the coal consumption, oil consumption and natural gas consumption of the provinces in the China Energy Statistical Yearbook [5]. For the sake of data integrity, this paper only calculates the total energy consumption of provinces except Tibet, Hong Kong, Macao and Taiwan in 2010–2014. The province's GDP, population data, and the proportion of the secondary industry come from the China Statistical Yearbook [6].
2. Emissions differences after carbon trading policy implementation

In order to effectively evaluate the emission reduction effect of Carbon Trading Pilot Policy and the opening of carbon trading market, carbon emission data of all Chinese provinces except Tibet, Hong Kong, Macao and Taiwan from 2010 to 2014 were selected for analysis. In 2011, China implemented and established the Carbon Trading Pilot Policy, and the comparison between 2010 and 2012 can reflect the effect of the carbon trading pilots. 2013 is the year in which the carbon trading pilots actually started trading, and the comparison between 2012 and 2014 is selected to reflect the policy effect of carbon trading. The comparison between 2010 and 2014 can reflect the emission difference before and after the whole Carbon Trading Policy.

Carbon emissions from carbon trading pilot and non-pilot were compared in three time groups in 2010 and 2012, 2012 and 2014, 2010 and 2014 (Fig. 1). We found that carbon emission in non-pilot areas in 2014 and 2012 increased significantly compared to 2010. However, there was no significant difference between pilot and non-pilot areas in different years.

The absolute and relative changes of pilots and non-pilots in the three time groups were compared in Fig. 2. We found that in 2010 and 2012, the absolute and relative changes of carbon emission in pilot areas were significantly lower than those in non-pilot areas. In the two time groups of 2012 and 2014, 2010 and 2014, the absolute and relative changes in the pilot area were both negative. Non-pilot carbon emissions are increased continuously, the absolute and relative changes are both positive. However, with the progress of time, their relative growth decreases from 19.1% in 2010 and 2012 to 1.6% in 2014 and 2012.

Figure 1. Comparison of carbon emissions between carbon trading pilot and non-pilot in three time groups: (a) 2010 and 2012, (b) 2012 and 2014, (c) 2010 and 2014.

Figure 2. Absolute change (a) and relative change (b) of carbon emissions from carbon trading pilot and non-pilot in three time groups.
Paired t-test was used to determine whether there were significant differences in carbon emissions between pilot and non-pilot in the three time groups, and independent-samples t test was used to determine whether there were significant differences in absolute and relative changes between pilot and non-pilot in each event group. The results are shown in Table 1: there is a significant difference in the average carbon emission of the non-pilot areas in 2012 compared with that of the non-pilot areas in 2010, while there is no significant difference in the carbon emission of the pilot areas in the same group years. In 2014, carbon emissions in non-pilot areas increased compared with 2012, but there was no significant difference. In the same period, carbon emissions in pilot areas decreased, but the difference was also not significant. Therefore, as far as the t-test results are concerned, compared with the significant increase in carbon emissions in the non-pilot areas, the establishment of the pilot and the start of carbon trading have produced certain effects, but such effects have not yet caused significant differences in the average carbon emissions in the pilot areas between different years.

The independent-samples t test was used to analyze whether there were significant differences in absolute and relative changes between the pilot and non-pilot in three time groups. The results showed that only in the time group of 2010 and 2014, there was a significant difference in the absolute change of carbon emission between the pilot and non-pilot, while there was no significant difference in the other two time groups. Within the three time groups, there were significant differences in the relative changes between the pilot and non-pilot, which may be caused by relevant policies, but may also be caused by changes in population, GDP and industrial structure in different time periods.

Table 1. Results of independent-samples t test and paired t-test in three time groups.

| Stage          | Independent-samples t test | Paired t-test |
|----------------|----------------------------|---------------|
| 2010 and 2012  | absolute change            | pilot         |
|                | relative change**          | non-pilot***  |
| 2012 and 2014  | absolute change            | pilot         |
|                | relative change**          | non-pilot     |
| 2010 and 2014  | absolute change***         | pilot         |
|                | relative change**          | non-pilot***  |

*** is significant at the level of 0.01, ** is significant at the level of 0.05.

3. Analysis of emission reduction effects of Carbon Trading Pilot Policy

The idea of generalized linear model (GLM) and difference-in-differences were used to control the four variables of population, GDP, the proportion of secondary industry in GDP and the estimated emission reduction, to judge the impact of pilot and Carbon Trading Policy on carbon emissions. Since the data itself has a certain skew distribution, we use the natural logarithm of population, GDP, secondary industry's share of GDP, projected emission reductions, and carbon emissions of dependent variables.

As shown in Table 2, before the establishment of carbon trading pilot, whether population, GDP and other factors are controlled or not, whether carbon trading pilot has no significant impact on its carbon emissions. This indicates that the carbon emission of the pilot provinces and cities did not differ significantly from that of other provinces and cities before the Carbon Trading Pilot Policy. Introduction of whether to become a carbon trade pilot virtual variables, after controlling for other factors, only 2010-2012 the results significantly, slope were 0.031 (carbon trading pilot) and 0.323 (to become a carbon trade pilot), this shows that after considering the regional differences in the carbon trading pilot and the time before and after the transaction, the carbon trading pilot policy does help to reduce carbon emissions. There was no significant difference in carbon emissions between the two dummy variables.
representing time, whether to become a carbon trading pilot and whether to start carbon trading, indicating that the implementation of the two policies had no significant impact on carbon emissions before and after the pilot and non-pilot provinces were not considered. As a whole, population has little impact on carbon emissions. The impact of Carbon Trading Policy on carbon emissions is less than that of GDP, let alone the proportion of secondary industry. Its impact accounts for 70.7% and 29.3% of GDP and secondary industry.

| Table 2. Carbon trading pilot emission reduction effect GLM model slope. |
|---------------------------------------------------------------|
| Dependent variable: carbon emission of provinces and municipalities directly under the central government |
| 2010  | 2010-2014 | 2010-2014 | 2010-2011 | 2010-2012 | 2010-2013 | 2012-2014 |
| Carbon trading pilot \ | 0.38** | 0.504** | 0.319** | 0.288* | 0.366** | 0.377* |
| population \ | \ | 0.227* | \ | \ | \ | \ |
| GDP \ | 0.509** | 0.569** | 0.523** | 0.477** | 0.522** | 0.512** |
| The proportion of secondary industry \ | 1.321** | 1.172** | 1.325** | 1.387** | 1.316** | 1.226** |
| Estimated annual average emission reduction \ | \ | \ | \ | \ | \ | 0.116** |

*, ** and *** represent significant levels of 0.1, 0.05 and 0.01, respectively, \\ represents insignificant (P > 0.1)

It can be seen that the reduction of carbon emissions is attributed to the policy of establishing carbon trading pilot. This effect had a significant impact before and after the establishment of carbon trading pilot from 2010 to 2012, while the current implementation of carbon trading has not shown a significant reduction effect. In the long run, the carbon emission of carbon trading pilot is obviously different from that of carbon trading non-pilot, which may be because: the pilot provincial and municipal governments pay more attention to energy conservation and emission reduction, and publish a large number of relevant regulations, which also drive a series of changes such as industrial restructuring [7]. Pilot provinces and cities enterprises by policy constraints, have more sense of urgency and responsibility to reduce emissions.

4. Conclusion
Existing Carbon Trading Policy show that they slow down the relative increase of carbon emissions in the pilot areas, and their emission reduction effect is relatively obvious before and after the establishment of the pilot from 2010 to 2012. However, as time goes by, the emission reduction effects in the adjacent period become weak, and the carbon emission in the pilot and non-pilot provinces is differentiated.

On this basis, it is reasonable to believe that after the promotion of the national carbon market, China's carbon emissions of province scale will be better controlled. At present, the impact of Carbon Trading Policy on carbon emissions is far less than that of GDP and industrial structure. It can be seen that to achieve sustainable development and reduce carbon emissions, in addition to implementing relevant policies, it is more important to reduce carbon intensity, reduce the proportion of the secondary industry and actively develop cleaner tertiary industry [8].

Therefore, it is necessary to implement the national carbon market as soon as possible to promote the energy saving and emission reduction of national province scale.

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References

[1] X. Zhang, P. Shen, Research on carbon emissions trading mechanism from the perspective of law and economics. Future Develop. 39 (2015) 32-36.

[2] L. Rao, W. Zeng, F. Zhang, The enlightenment of EU carbon emissions trading Quota distribution mode to China. Environ. Prot. (2009) 66-68.

[3] W. Chen, Z. Wu, Carbon emissions allocation and carbon emissions trading. J. Tsinghua Univ. (Nat. Sci. Edit.) 12 (1998) 15-18.

[4] H. He, A preliminary study on the integration path of China's carbon emissions trading market. Jinan Univ. 2013.

[5] China Energy Statistical Yearbook, 2010-2012.

[6] China Statistical Yearbook, 2010-2012.

[7] J. Zhu, T. Zheng, J. Fang, Carbon emissions and social and economic development. Sci. Soc. 3 (2013) 1-13.

[8] T. Zheng, J. Zhu, S. Wang, J. Fang, When will China achieve its carbon emission peak? Natl. Sci. Rev. 3 (2016) 8-12.