The impact of carbon trading on China’s renewable energy investment: Case of CDM wind power projects

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Abstract. Taking the Clean Development Mechanism (CDM) wind power project as an example, this paper analyses the impact of carbon trading on China’s renewable energy investment. Based on the data of Certified Emissions Reductions (CERs) price and the registered volume of CDM wind power projects in China from 2008 to 2015, the correlation between the investment decision of CDM wind power projects and the carbon trading price is tested. This paper also establishes a profitability evaluation model for CDM wind power projects, calculates the internal rate of return (IRR) of the projects, and uses the benchmark analysis method to evaluate the economic competitiveness and investment attractiveness of the projects with or without the income of CERs. Additionally, the sensitivity analysis is conducted for the main investment and income variables. It is concluded that the investment decision of China’s CDM wind power project is closely related to the current carbon trading price, and the carbon trading income is the main method to improve the profitability of renewable energy projects.

1. Introduction
The Kyoto Protocol is the first international agreement signed by developed countries for mandatory quantitative emission reduction of greenhouse gases, marking the world’s beginning to take seriously the growing climate change[1]. The agreement establishes the Clean Development Mechanism (CDM) as one of the three flexible carbon reduction mechanisms that allows Annex I countries to achieve their emission reduction commitments by purchasing certified carbon emission equivalents (CERs) from developing countries[2].

Since the CDM has created an incentive mechanism by allowing the sale of CERs, giving the renewable energy revolution a nudge in the right direction, the renewable energy has achieved remarkable development[1]. According to the International Renewable Energy Agency, global renewable energy generation capacity has tripled since 2005, with an average annual growth rate of 8.3% over the past seven years and cumulative power generation of 2,179,000MW[3].

A number of current researches focus on the impact of the CDM on renewable energy development. For example, Q Wang, Y Chen[4] and Lewis[5] analysed the role of CDM in promoting renewable energy development in China by reviewing the CDM activities, finding that CDM is an indispensable incentive and a viable choice to promote renewable energy deployment in China. S M Rahman et al.[6] examined the costs of electricity generation by the power projects under the CDM, and calculated the levelized cost of electricity for each project, concluding that CDM enables renewable electricity to be more competitive. Z Y Zhao et al.[7] constructed a financial model of net present value to analyse the cost price of wind power electricity with or without CERs income, and concluded that the CDM has a
significant impact on the cost price of wind power electricity.

2. Correlation test

Based on the data of registered CDM wind power projects in China[8] and the domestic CERs price from 2008 to 2015[9], this paper verifies the correlation between them.

2.1. General situation of CERs price and projects

As shown in figure 1, the CERs price increased in the first half of 2008, and reached the maximum value of higher than 20 euros/tCO$_2$. However, in the second half, the carbon trading price decreased significantly, and basically remained around 10-15 euros/tCO$_2$. Subsequently, due to the changes of international situation and the impact of the EU financial crisis, China’s CERs price dropped sharply to less than 0.5 euro/tCO$_2$ since 2013. The monthly registered volume of China’s CDM wind power projects continued to increase until 2013, especially during 2012. However, at the beginning of 2013, it dropped sharply, and eventually fell below 5 per month.

![Figure 1. Trend of China’s CDM wind power projects and CERs prices.](image1)

![Figure 2. Trend of China’s CDM wind power projects and CERs prices.](image2)

According to the project design document (PDD) of CDM projects, in general, it takes 6-7 months for the UNFCCC to accept the project from the establishment of project investment plan[10]. In order to eliminate the hysteresis effect, as shown in figure 2, we shift the projects curve forward for 6 months. From April 2011 to June 2012, the domestic CERs price declined rapidly, but the registered volume of CDM wind power projects increased during this period. That is because, on the one hand, China’s CDM has already formed a certain degree of scale effect, and on the other hand, there indeed exists inevitable hysteretic quality in the CERs trading market. Thus, the investors of CDM could not make reasonable adjustments to the rapid decline of CERs price in such a short period of time.

2.2. Spearman coefficient

As shown in figure 2, excluding the anomalous interval (April 2011 to June 2012), the domestic CERs price and the registered volume of wind power projects show a similar trend of increase and decrease intuitively. In order to test whether there is an objective correlation between them, this study intends to calculate the Spearman correlation coefficient between them by

$$\rho_{xy} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \cdot \sum(y_i - \bar{y})^2}}$$

(2.1)

where x and y denote the rank sets of the domestic CERs price and the registered volume of wind power projects respectively.
Table 1 shows the Spearman coefficient between the CERs trading price and the registered volume of CDM wind power projects in China from 2008 to 2015 (excluding April 2011 to June 2012). The results show that the significance coefficient sig.=0.000<0.01, indicates that there is a significant correlation between domestic CERs transaction price and CDM registration volume at the level of 0.01, and the correlation coefficient r=0.676>0.4, indicates that there is a close relationship between them.

Table 1. Spearman Correlation between CERs price and the number of wind power projects.

|            | CERs Price | Projects |
|------------|------------|----------|
| Spearman Rho |            |          |
| CERs Price  | Spearman Correlation | 1.000 | .676** |
|             | Sig. (2-tailed)      | .000    | -      |
|             | N                      | 60      | 60     |
| Projects    | Spearman Correlation  | .676**  | 1      |
|             | Sig. (2-tailed)       | .000    | -      |
|             | N                      | 60      | 60     |

** Correlation is significant at the 0.01 level (2-tailed)

3. IRR model for the CDM wind power projects
For further research, this study intends to establish an economic evaluation model for CDM wind power projects to analyse the impact of CERs income on project investment attractiveness.

The revenue of CDM wind farm mainly includes the income from selling electricity and CERs, given respectively by

$$Revenue_t = Q_t \times P_t, \quad t \in [2, 21]$$  \hfill (3.1)

$$CICome_t = 98\% \times CERs_t \times CP_t, \quad t \in [2, 8]$$  \hfill (3.2)

where $Revenue_t$ denotes the income from selling electricity, $Q_t$ is the annual power supplied to the grid (kWh), $P_t$ is the tariff (RMB/kWh), $CICome_t$ denotes the income from carbon trading, and $CP_t$ is the CERs price (RMB/tCO$_2$).

The expenditure of CDM wind power farm mainly includes the construction investment, the operation and maintenance (O&M) cost, the depreciation, the financial cost and the taxes[11]. Among them, the O&M cost, including the material cost, the salary, the repair cost, the insurance and other costs, can be expressed by

$$O & M_t = Materials_t + Salary_t + Repair_t + Insurance_t + Other_t, \quad t \in [2, 21]$$  \hfill (3.3)

The depreciation can be expressed by

$$Depreciation_t = fixedassets \times \frac{1 - residual}{life}, \quad t \in [2, 16]$$  \hfill (3.4)

where residual denotes the rate of residual value (5%), and life is the depreciation period (15years).

The financial cost mainly refers to the fees used to repay bank interest, and can be expressed by

$$Interest_t = (Loan \cdot i - Repay_t) \cdot (1 + i)^{t-1} + Repay_t, \quad t \in [2, 16]$$  \hfill (3.5)

where Loan is the long-term loan (RMB), $i$ is the interest rate of long-term loan (%), and Repay$_t$ denotes the annual repayment, as the average capital plus interest method is adopted in this study, it can be expressed by
The IRR model can be written as
\[
\sum_{t=1}^{n} (CI - CO_t) (1 + \text{IRR})^{-t} = 0, \quad t \in [2, 21]
\] (3.12)

where \((CI - CO_t)\) denotes the net cash flow in each year, given by
\[
(CI - CO_t) = Revenue_t + Loan_t + CIcome_t - Contraction_t - O & M_t - Repay_t - TAX_t
\] (3.13)

from equation (3.1)-(3.3) and equation (3.6)-(3.10).

4. Results and analysis

Since 49.5MW is the most common installed capacity of China’s CDM wind power projects, this study selects 35 CDM wind power projects with installed capacity of 49.5MW across China randomly, and calculated the average value of indicators of them as the experimental data.

4.1. Results

When the CERs trading price is assumed to be 10 euros/tCO₂, the IRR of projects with and without CERs income are calculated respectively, and compared with the benchmark IRR (8%) of China’s power industry[13], as shown in table 2.

| Without CERs income | benchmark | With CERs income |
|---------------------|-----------|------------------|
| IRR                 | 6.49%     | 8%               | 9.22%            |

Table 2. IRR of wind power projects with or without CERs income.
The project IRR (without carbon trading benefit) is 6.49%, which is lower than the benchmark (8%). However, taking carbon trading into account, on the basis of same parameters as above, the IRR goes up to 9.22%, which is better than the benchmark.

4.2. Sensitivity analysis
In order to further assess the profitability of the projects, sensitivity analysis is conducted, and the following four parameters are considered: the total project cost, the annual power supplied to the grid, the tariff and the O&M costs. The results of the sensitivity analysis show in the figure 3 below.

![Figure 3. Sensitivity analysis of wind power project.](image)

As shown in the sensitivity analysis, even the variation range of the uncertain factors reaches 10%, the project IRR could not reach the benchmark. Furthermore, the table 3 presents the analysis for each variable change that will make the project IRR reach the benchmark (8%).

| Total projects investment | O&M costs | Supplied electricity | Tariff |
|---------------------------|-----------|----------------------|--------|
| range                     | -10.6%    | -47.9%               | +10.8% |

However, none of these adjustments shown in table 3 can be achieved. Since the total value of main contrasts of equipment and engineering accounts have been increasing in recent years[14], a decrease of the total project investment is unlikely occurred. And CPI/PPI in China increased significantly year on year, especially the cost index of materials and labour, which made it almost impossible to reduce the O&M costs by 47.9%. According to relevant notices published by NDRC[15], there is no chance for the tariff to increase 10.8%. Moreover, as the supplied electricity is estimated based on 30 years wind resources analysis and simulation by professional software, it is impossible to increase the supplied electricity by 10.8%.

5. Conclusion
By examining the correlation between China’s CDM wind power project investment and domestic carbon trading prices, constructing an IRR model to analyse the profitability of wind power projects with or without carbon trading income, and conducting sensitivity analysis of key economic variables, this paper provides the following conclusions:

- There is a positive correlation between the registered volume of China’s CDM wind power projects and the carbon trading price, that is to say, the investment decision of CDM wind power project is largely affected by the current carbon trading price. Generally, when the CERs price is higher, the more CDM wind power projects will be invested.
- CDM wind power projects have no investment appeal without carbon trading revenue, and through sensitivity analysis, we can find that even the adjustments of key variables within a reasonable
range cannot make the IRR of the project reach the benchmark.

- Carbon trading revenue can significantly improve the economic competitiveness and investment attractiveness of wind power projects and is a key factor in encouraging and supporting the investment in wind power projects. Therefore, it is crucial to improve the domestic carbon trading market and develop the domestic voluntary emission reduction mechanisms to promote the investment and development of renewable energy.

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