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Abstract

This paper reviews the researches related to international carbon emission right trading. Based on the analysis of marginal abatement curves theory, it has been demonstrated that the fact that different countries or districts have different marginal abatement costs of carbon emission upon respective abatement promise gives rise to international carbon emission right trading. Furthermore, this paper proposes that developing countries should actively participate in the international carbon emission right trading in order to obtain due market benefits. Then, on the basis of the two-phase model, this essay also discusses the optimal exports scale of carbon emission right and its determinant factors, and evaluates the optimal export quantity of carbon emission right for China at the first phase.

1. Introduction

The Kyoto Protocol signed in December 1997 established a flexible abatement mechanism, in order to facilitate the international carbon emission right trading to become a rapidly emerging market. However, the leading power, especially the pricing power is mainly in the hand of developed countries listed in Annex B Nation, which could reduce the price of international carbon emission right to an extremely low level by transferring carbon emission right through import and export transactions (i.e. carbon emission right transfer implicit in trading) or by taking advantage of information asymmetry, or the power to formulate international rules. Although over the recent years, China has played an active role in dealing

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with climatic change, in enhancing energy saving and emission reduction, as well as in international carbon emission trading market and the export of carbon emission right, China is now facing more and more international pressure on emission reduction.

2. Relevant Researches

Along with the increasing global attention on the climate problems, more and more researches on the carbon emission right trading have been conducted. W.J. Baumo & W.E. Oates (1971), T. Tietenberg & L. Lewis (1985), Jacoby and Ellerman (2002), Burtraw (2009) et al. were mainly concerned with the desirability of carbon emission right trading, and the majority of them supported the idea that government should guide private decisions through market behaviours instead of direct intervention. R. T. Sterner (2002), Klepper G. & S. Peterson (2004), compared the application scopes and pros & cons of carbon emission right trading with those of other environmental policy tools from the perspectives of economic costs, static and dynamic efficiency, and the political practicability, etc. Stavins R.N (1995), Cason (1995, 1996), Dewees D. (2001), R. A. Muller & S. Mestelman (2002), C. Fischer (2003), and N. J. Buckley (2003, 2004) et al. investigated the institutional design of carbon emission right trading and its efficiency. After the Copenhagen Conference of December 2009, a large number of scholars in China began to focus on the issue of carbon emission right, such as Jin Yunhui & Liu Xue (2000), Zeng Gang & Wan Zhihong (2009), Yang Ji (2010), Zhao Liming & Zhang Han (2010), Fu Qiang & Li Tao (2010), and Shi Yadong & Zhong Maochu (2010) et al. The existing studies are mainly concerned with carbon emission right trading market between corporations in one country or one district, with their starting point concentrated on the fulfillment of carbon emission abatement by developed countries, without looking into carbon emission right trading on the global market level. What is especially lacking is the discussion on the development of international carbon emission market from the standpoint of developing countries.

3. Analysis of International Carbon Emission Right Trading From the Perspective of Cost

3.1 Marginal Abatement Cost Curves

Marginal Abatement Curves (MACCs) can be obtained from MIT’s Emission Prediction and Policy Analysis (EPPA) model. The EPPA model divide the globe into the following 12 districts: USA, Japan (JPN), European Economic Community (EEC), other OECD countries (OOE), Eastern Europe (EET), Former Soviet Union Countries (FSU), Energy Export Countries (EEX), China (CHN), India (IND), Dynamic Asian Economies (DAE), Brazil (BRA), and other countries of the world (ROW). Among the above 12 districts, the first six belongs to the Annex B countries, in which Tokyo Protocol clearly provides for the abatement promise of the Annex B countries in the first phase (2008-2012), and the rest of the six countries are Non-Annex B Countries.

The marginal abatement cost function could be calculated through regressive analysis using EPPA model, with its expression: \( P = MC = aQ_t^2 + bQ_t \), where \( Q_t \) denotes the abatement quantity with the period \( T \) (Mton), and \( MC \) represents the marginal abatement cost (USD). Ellerma & Decaux (1998) applied EPPA model to evaluate the marginal abatement cost function of the 12 districts in 2010, and the resulting coefficients are shown in Table 1. All the equations showed a high degree of fitting, all the value of \( R^2 \) being larger than 0.99.
Table 1. Regressive Analysis of Every District’s Marginal Abatement Cost Function (Unit: USD, Mton)

<table>
<thead>
<tr>
<th>District</th>
<th>Coefficient a</th>
<th>Coefficient b</th>
<th>$R^2$</th>
<th>District</th>
<th>Coefficient a</th>
<th>Coefficient b</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>0.0005</td>
<td>0.0398</td>
<td>0.9923</td>
<td>EEX</td>
<td>0.0032</td>
<td>0.3029</td>
<td>0.9983</td>
</tr>
<tr>
<td>JPN</td>
<td>0.0155</td>
<td>1.8160</td>
<td>0.9938</td>
<td>CHN</td>
<td>0.00007</td>
<td>0.0239</td>
<td>0.9992</td>
</tr>
<tr>
<td>EEC</td>
<td>0.0024</td>
<td>0.1503</td>
<td>0.9951</td>
<td>IND</td>
<td>0.0015</td>
<td>0.0787</td>
<td>0.9970</td>
</tr>
<tr>
<td>OOE</td>
<td>0.0025</td>
<td>-0.0986</td>
<td>0.9981</td>
<td>DAE</td>
<td>0.0047</td>
<td>0.3774</td>
<td>0.9996</td>
</tr>
<tr>
<td>EET</td>
<td>0.0079</td>
<td>0.0486</td>
<td>0.9973</td>
<td>BRA</td>
<td>0.5612</td>
<td>8.4974</td>
<td>0.9997</td>
</tr>
<tr>
<td>FSU</td>
<td>0.0023</td>
<td>0.0042</td>
<td>0.9938</td>
<td>ROW</td>
<td>0.0021</td>
<td>0.0805</td>
<td>0.9967</td>
</tr>
</tbody>
</table>


3.2 Analysis on Model of the Starting Point of International Carbon Emission Right Trading

Abatement cost functions vary for different countries or districts. According to Coase Theorem and Pareto Optimality, when transaction and transportation costs are not taken into consideration, the market achieves equilibrium with the minimum transaction cost (or the maximum profit). Then, there exists the possibility of international carbon emission right trading between Annex B countries and Non-Annex B countries, which is give detailed discussion below.

Suppose there is a carbon emission right trading market composed of one buyer and one seller. Here the cases of CHN and EEC are taken as examples. CHN’s marginal abatement cost quadratic function is as follows:

$$MC_C = a_C Q_C^2 + b_C Q_C$$  \hspace{1cm} (1)

CHN’s abatement cost function is obtained through integral calculus:

$$TC_C = \frac{1}{3} a_C Q_C^3 + \frac{1}{2} b_C Q_C^2$$  \hspace{1cm} (2)

Where $MC_C$ represents CHN’S marginal abatement cost of carbon emission; $a_C$ and $b_C$ represent the quadratic term and first-order term coefficient of CHN’s marginal abatement cost of carbon emission function, respectively; $Q_C$ represents the abatement quantity in the trading, and $TC_C$ represents the total cost of abatement.

Similarly, the quadratic function of EEC’s marginal abatement cost is as follows:

$$MC_E = a_E Q_E^2 + b_E Q_E$$  \hspace{1cm} (3)

The abatement cost function is obtained through integral calculus:

$$TC_E = \frac{1}{3} a_E Q_E^3 + \frac{1}{2} b_E Q_E^2$$  \hspace{1cm} (4)

Where $MC_E$ represents EEC’s marginal abatement cost of carbon emission; $a_E$ & $b_E$ represent the quadratic term coefficient and first-order term coefficient of EEC’s marginal abatement cost of carbon emission, respectively; $Q_E$ represents the abatement quantity of EEC, and $TC_E$ represents the total cost of EEC’s abatement.

The abatement cost of EEC is higher than that of CHN. Due to the global emission equivalence of greenhouse gases such as CO2 and the guarantee of flexible carbon emission trading mechanism instituted by Tokyo Protocol, EEC has the right to purchase carbon emission right from CHN in order to achieve its own carbon abatement goal. Suppose EEC’s quantity of abatement obligation prescribed in Tokyo Protocol is at least $Q_{kE}$, and the quantity of carbon emission right that can be purchased...
internationally is $Q_{EB}$, with $Q_{KE} \leq Q_E + Q_{EB}$. According to the above assumption that there is only one buyer and one seller, the quantity of CHN’s export emission right is $Q_{EB}$.

After the transaction between CHN and EEX has started, the model of carbon emission right can be expressed as follows:

$$\max TRC_c = P_{CS}Q_{EB} - \left(\frac{1}{3}a_cQ_c^3 + \frac{1}{2}b_cQ_c^2\right) \quad \text{s. t.} \quad Q_{eb} \leq Q_c \quad (5)$$

$$\min TCE_E = \frac{1}{3}a_EQ_E^3 + \frac{1}{2}b_EQ_E^2 + Q_{EB}P_{EB} \quad \text{s. t.} \quad Q_{ae} \leq Q_E + Q_{EB} \quad (6)$$

Where $TCE_E$ represents the total cost for EEC to fulfill its abatement goal through its own effort in abatement and the purchase of carbon emission right internationally; $Q_{EB}$ represents the abatement quantity that EEC has purchased from CHN; $P_{EB}$ represents the unit price at which EEC purchase emission right from CHN; $TRC_c$ represents the total profits that CHN has gained by selling its carbon emission right, and $P_{EB}$ represents the unit price at which CHN sells its carbon emission right. Without the consideration of transaction cost, etc., the market clearing can achieve the equality between EEC’S purchase price and CHN’s selling price, i.e. $P_{EB} = P_{CS}$.

3.3 Graphical Analysis on the Results of International Carbon Emission Right Trading

According to Figure 1, Curves $R_E$ and $R_C$ denote the marginal abatement costs of EEC and CHN, respectively. Before the transaction, their respective marginal abatement costs are $P_E$ and $P_C = 0$, respectively, and apparently $P_E > P_C$. After the transaction, the marginal abatement costs of EEC and CHN, i.e. the market clearing price $P^e = P_{EB} = P_{CS}$, and their respective abatement quantities are $Q_E$ and $Q_C$, respectively. The quantity that EEC imports ($Q_{ae} - Q_E$) equals the quantity that CHN sells. EEC’s total cost of the fulfillment of the abatement goal is reduced from $HOQ_{ke}$ to $OMGQ_{ae}$ by importing carbon emission right. And the saved cost is the net earning denoted as $MGH$ in the transaction; in the case of CHN, the export earning is $OQQ_{ce} N$, from which the cost $QQ_{ce} N$ is deducted to obtain the net earning $ONP^e$. It can be known from such analysis that both EEC and CHN can benefit themselves by way of carbon emission right trading, in which the former reduces its abatement cost, and the latter gains the export earning. In this way, a win-win situation occurs, and this is precisely the logic starting point for international carbon emission right market to form and develop.

![Figure 1. Marginal Abatement Curves](image-url)
4. Analysis on Optimal Exports Scale of China’s Carbon Emission Right

4.1 The calculation of Implicit Function of Optimal Exports Scale of International Carbon Emission Right

Two-phase model is established to analyze the solving function of Non-Annex B country’s optimal exports scale of carbon emission right, which doesn’t assume the abatement obligation in the first phase, but in the second phase.

The assumed conditions of the two-phase model is listed as follows: (1) Suppose a country does not assume the abatement obligation in phase $t_1$, and the corresponding abatement quantity $Q_1$ can be converted into transferrable emission right, all of which are exported; (2) Suppose this specific country is obliged to reduce emission $E_2$ in phase $t_2$, in order to fulfill abatement goal, and this country has to import the emission right $Q_m$ in addition to achieve the abatement quantity $Q_2$; (3) Suppose the country’s total quantity of carbon emission abatement is $Q$ in phase $t_1$ and $t_2$, and $Q = Q_1 + Q_2$; (4) Suppose the international carbon emission market is in perfect competition, then the transaction price is determined by the market; (5) The abatement cost function is $C_t = C_t(Q_t)$ ($t = 1, 2$, and the value of $t$ is the same below ), and the marginal abatement cost function is $MC = C_t'(Q_t)$, which is a strictly increasing, and continuously differentiable function with effective $Q_t$; (6) The expenses arising from the transaction of carbon emission right are dismissed.

By totaling up the net values’ present value of both phases, the following can be obtained:

$$net = P_1 \cdot Q_1 - C_1(Q_1) + \delta [-C_2(Q_2) - P_2 \cdot Q_m]$$ (7)

After the substitution of $Q_2 = Q - Q_1$, the first-order derivative of $Q_1$ can be obtained:

$$net' = P_1 - C_1' + \delta \cdot C_2' - \delta \cdot P_2$$

The second-order derivative of $Q_1$ is obtained as follows: $net'' = -C_1'' - \delta \cdot C_2''$

If the function $MC = C_t' = C_t'(Q_t)$ is strictly increasing with effective $Q_t$, then $C_1'' > 0 \ldots C_2'' > 0$. Therefore, $net'' < 0$ and $net'$ are convex functions. When the first-order function $net' = 0$, the value of $net$ corresponding to the value of $Q_1$ reaches its maximum.

When $net' = 0$, then $C_1(Q_1) - \delta \cdot C_2(Q_2 - Q_1) = P_1 - \delta \cdot P_2$

It is thus clear that if the marginal abatement cost function $C_t = C_t(Q_t)$, the prices of carbon emission right $P_1$ and $P_2$, the total emission quantity $Q$ and discount coefficient are already known, then the optimal abatement quantity $Q_1^*$ in phase $t_1$, i.e. the optimal exports scale of this phase can be solved.

4.2 Calculation of Optimal Exports Scale of China’s Carbon Emission Right

If China’s marginal abatement function, the total abatement quantity in both phases, the price of emission right, and discount coefficient are all known, then we can solve the value of the optimal export quantity $Q_1^*$ of China in phase according to Formula (8). Ellerman et al. mentioned above have obtained China’s marginal abatement function in 2010 as $C_t = 0.00007Q_t^2 + 0.0239Q_t$ with the assistance of EPPA regressive analysis, which could be viewed as the marginal abatement function of the first phase. Considering the comparable factors such as economic scale and emission quantity, it is preferable to replace the function above with $C_t = 0.0005Q_t^2 + 0.0398Q_t$, the first phase abatement cost function of USA, which keeps a relatively low level of abatement cost. Shortly before the Copenhagen Conference,
China published its goal of reducing carbon dioxide emission for every unit of GDP by 40%-45% in 2020 compared with 2005. Qilu Securities anticipated that in order to achieve this goal, the total quantity of carbon dioxide emission in China should be 6 to 7 billion tons in Series Report II on Environmental Conservation and Chemical Engineering Industry published on May 10th, 2010. In this paper, it is assumed that the total abatement quantity is 6.5 billion tons, i.e. \( Q = 6500 \text{ Mton} \). Based on the existing researches of Shi Yadong (2010) et al, the values of \( P_1 \) & \( P_2 \) are set to be 16 dollars according to the quoted prices of CER and EUA and exchange rates of ECX Exchange, If 2025 is chosen in the calculation of the second phase, then the calculation period spans 15 years. Domestic discount coefficient \( \delta \) has a close relationship with bank interest rate. After obtaining the interest rate level between 1989 and 2010, after the weighted mean of annual interest rate is 5.13\%m, and \( \delta = 0.472 \).

Based on the above estimated statistics, the optimal exports scale of China’s first-phase carbon emission right is calculated as 2.855 billion tons, which may require further adjustment by taking into account of China’s abatement cost, the price of emission right market and the market interest etc. At present, this value can be used as the reference data during China’s international negotiation on carbon emission or in the cooperation in carbon emission with other developing countries.

5. Conclusion

The Annex B countries and Non-Annex B Countries differ in marginal abatement cost, and they can achieve win-win through the carbon emission right transaction. Developing countries should participate in the international carbon emission right transaction actively, so as to gain due market benefits by way of reasonable export of carbon emission right. Non-Annex B countries, which have no abatement obligation in the first phase, should take part in the international carbon emission right transaction in a rational way, and should not sell the carbon emission right—the public resource with IP(Property right) character—cheaply. There exist several factors influencing the export quantity of carbon emission right of Non-Annex B Countries in the first phase. China’s optimal exports scale of first-phase carbon emission right is estimated to be 2.855 billion tons. However, this figure needs to be further adjusted according to abatement cost, carbon emission right price, its own abatement capacity and discount rate etc.

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