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Marginal abatement costs of carbon dioxide in China: A nonparametric analysis

Qunwei Wang[a,b*], Qinjun Cui[a], Dequn Zhou [b], Sisi Wang [b]

[a]*School of Bussiness,Soochow University, 50 Donghuan Road, Suzhou 215021,China*
[b] *Center for Soft Energy Sciences, Nanjing University of Aeronautics and Astronautics, 29 Yudaostreet, Nanjing 210016, China*

Abstract:

The estimates of abatement costs about CO_2 can provide useful information for policy-makers. With the framework of production theory, a marginal abatement costs model is established using the nonparametric method, and empirical results about China in 2007 are found in this paper. The two CO_2 reduction strategies, maintaining the level of CO_2 or reducing CO_2 and expanding GDP at the same time, impact potential GDP greatly. 143.5 millions CO_2 reduction means 35.1billions GDP loss and the marginal abatement cost of CO_2 is 475.3yuan/ton on average.

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Kewords: marginal abatement costs, carbon dioxide, directional distance function, data envelopment analysis

1. Introduction

After over 30 years of reform and opening up, China's economy has rapidly developed. Meanwhile, the quantity of energy consumption and carbon dioxide emissions are increasing fast. At present, China has overtaken the United States as the world's biggest producer of CO_2, which has given rise to problems of environmental pollution and ecological destruction. Before Copenhagen conference, Chinese government announced that it will cut its CO_2 emissions per unit GDP by 40 to 45% in 2020 from 2005. It is a major challenge for our government to achieve this target at minimum cost.

The estimates of abatement costs about CO_2 can provide useful information for price subsidy in carbon emissions trading market, and it is also important for other related polices. So, some scholars have researched on the abatement costs (Coggins and Swinton, 1996; Färe et al., 2005; Murty and Kumar, 2007; Gao et al., 2009). These literatures basically focus on the costs in developed countries, e.g. USA and Spain. The methods used are almost econometric, MARKAL-MACRO model and computable

* Corresponding author. Tel.: +86 13921407218
E-mail address: .wqw0305@yahoo.com.cn

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general equilibrium (CGE).In this paper, we try to use nonparametric method to analysis marginal abatement costs of carbon dioxide (MAC) in China, which may helpful for the policy-maker.

2. Methodology

2.1. Environmental production technology

Consider an area in which desirable outputs and undesirable outputs are jointly produced. We denote the inputs by $x=(x_1,x_2,\cdots,x_n)\in R_N^+$, gross domestic product (GDP) (y), is the only desirable output and CO_2 (c) is the only undesirable output. The production technology can be presented as $P(x)=\{(y,c):(x,y,c)\in T\}$ .We can find that production technology set T includes environmental factors, which is different from traditional production activities. So this technology is always called environmental production technology (Zhou et al., 2008). Except for the strong disposability of inputs and GDP, the output set $P(x)$ is assumed to have the following two properties according to Färe et al. (2007).

CO_2 has weak disposability, $(y,c)\in P(x)$ and $0\le\theta\le 1$ imply $(\theta y,\theta c)\in P(x)$.In a word, a proportional constriction of outputs is feasible. It is costly in terms of GDP to decrease production of CO_2. $P(x)$ has "null-jointness", $(y,c)\in P(x)$ and $c=0$ imply $y=0$.It means that GDP cannot be produced without producing CO_2.

In order to model the ideas mentioned above, we introduce the concept of directional distance function, and it is defined as function (1):

$$D(x,y,c;g_y,-g_c)=\sup\{\beta:(y+\beta g_y,c-\beta g_c)\in P(x)\} \quad (1)$$

where $g=(g_y,-g_u)$ is a direction vector of the output, which denotes a positive expansion for GDP and a negative expansion for CO_2.

Further, we suppose that there are K regions and (x,y,c) is the input-output vector for region k'. Then the value of directional distance function can be calculated by the linear program, function (2). It can be seen that function (2) satisfies all the properties discussed in the forgoing.

$$\begin{aligned} &D(x^{k'},y^{k'},c^{k'};g_y,-g_c)=Max\,\beta \\ &s.t.\sum_{k=1}^{K}\lambda^k x_n^k\le x_n^{k'};\quad \sum_{k=1}^{K}\lambda^k y^k\ge y^{k'}+\beta g_y;\sum_{k=1}^{K}\lambda^k c^k=c^{k'}-\beta g_c;\ \lambda^k\ge 0; \\ &n=1,2\cdots,N;\ k=1,2\cdots,K \end{aligned} \quad (2)$$

2.2. Measuring marginal abatement costs of CO_2

We have two different CO_2 reduction strategies at least based on the choices of direction vector. The first strategy aims at producing GDP as much as possible when inputs and CO_2 are given. It is consistent with the idea of Kyoto Protocol that requiring some countries to control their emission levels in 1990. For this strategy, $g=(g_y,0)$. As shown in Fig.1, region A can move to point B by increasing GDP represented by segment AB, thus realize the maximum of GDP and CO_2 is also not increased.

If $g=(g_y,-g_c)$, we have the second CO_2 reduction strategy. It requires a proportional increase of GDP and a reduction of CO_2 simultaneously, which matches the policy of development with quality and speed. For this situation, region A moves along the direction of AC to point C shown in Fig.1.

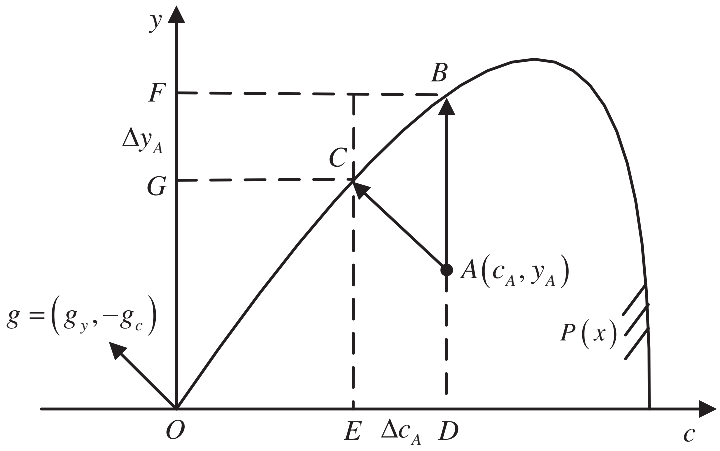

Fig.1. Illustration of directional distance function

Comparing these two kinds of CO_2 reduction strategies, we find that both reductions and potential GDP are different. And this difference could help us to measure marginal abatement costs of CO_2. Suppose that β_1 and β_2 are the solutions of function (2) when $g=(g_y,0)$ and $g=(g_y,-g_c)$ respectively. Then, for region A, the potential GDP is $(1+\beta_1)y_A$ and its quantity of CO_2 emissions is c_A with the first CO_2 reduction strategy. Meanwhile, $(1+\beta_2)y_A$ and $(1-\beta_2)c_A$ are the potential GDP and CO_2 with the second strategy.

We can find that the second CO_2 reduction strategy has more reduction than the first one, like region A in Fig.1, but its potential GDP is also less. The balance of GDP is $\Delta y_A = FG = (\beta_1-\beta_2)y_A$, and it is equal to the GDP increasing when the CO_2 reduction, $\Delta c_A = DE = \beta_2 c_A$, is given up. Thus, the ratio of Δy_A and Δc_A could tell us the marginal abatement costs of CO_2.

3. Empirical application

3.1. Data

Our study uses the data of 28 provinces in China to measure marginal abatement costs, and the period is 2007. According to the hypothesis in methodology, we assume that each province uses its capital stock, total labor force, total energy consumption as inputs and produces one desirable output in the form of GDP and one undesirable output in the form of CO_2. Capital stock is estimated by Shan (2008) in 1952 prices. Labor, energy and GDP are from China Statistical Yearbook and China Energy Statistical Yearbook. CO_2 emissions data are generated by the consumption of fossil energy.

3.2. Results and discussion

Using function (2), we calculate the expansion coefficients, β_1 and β_2, firstly (Table 1).It indicates that China's potential GDP growth is 65.6% maintaining the existing level of CO_2 emissions in 2007. Especially Guizhou, Qinghai and Xinjiang, their values of β_1 are more than 1, showing their economic development is far behind Tianjin, Shanghai, Liaoning et al. The average value of β_2 is 0.397 and it is consistent with our expectations.

Table1 Marginal abatement costs of CO_2

	β_1	β_2	Δy (billion)	Δc (Mt)	MC (yuan/ton)
Beijing	0.372	0.157	48.6	16.9	2878.9
Tianjin	0.000	0.000	0.0	0.0	——
Hebei	0.834	0.406	145.0	280.5	516.9
Shanxi	0.000	0.751	*	590.0	——
Inner Mongolia	0.837	0.792	6.0	398.4	15.2
Liaoning	0.000	0.000	0.0	0.0	——
Jilin	0.713	0.447	31.1	106.6	291.5
Heilongjiang	0.721	0.447	36.1	142.1	253.7
Shanghai	0.000	0.000	0.0	0.0	——
Jiangsu	0.307	0.306	0.1	185.4	0.7
Zhejiang	0.280	0.217	24.0	89.5	267.6
Anhui	0.534	0.381	16.7	105.1	158.6
Fujian	0.000	0.000	0.0	0.0	——
Jiangxi	0.975	0.605	39.2	90.8	431.3
Shandong	0.421	0.409	6.7	395.0	17.0
Henan	0.979	0.660	74.0	424.9	174.2
Hubei	0.652	0.340	58.1	105.1	552.9
Hunan	0.855	0.412	65.3	121.6	537.3
Guangdong	0.526	0.318	93.1	133.9	695.0
Guangxi	0.411	0.222	20.5	29.4	695.0
Sichuan	0.389	0.222	45.0	83.0	542.3
Guizhou	2.615	0.808	77.2	231.2	334.1
Yunnan	0.000	0.000	0.0	0.0	——
Shaanxi	0.540	0.623	*	160.6	——
Gansu	0.977	0.594	30.9	94.9	325.5
Qinghai	1.527	0.621	12.6	19.8	636.1
Ningxia	0.945	0.655	7.1	75.8	93.2
Xinjiang	1.945	0.730	76.6	135.8	563.7
Mean	0.656	0.397	35.1	143.5	475.3

Note:* indicates the balance of GDP is negative for this province

Comparing these two different CO_2 reduction strategies, it shows obviously that most provinces can reduce more CO_2 when they adopt the second strategy, and the average reduction balance is 143.5 millions. Meanwhile, these provinces lost 35.1 billions GDP on average. As a result, we obtain the average marginal abatement costs. That is 475.3yuan/ton. It is slight larger than the actual situations in some foreign countries (Reddy et al., 2009). However, it is not difficult for us to understand this difference. Because we just give the theoretical cost. This does not affect the guidance for related policies.

From the view of abatement costs in different provinces, some regions are very special. Tianjin, Liaoning, Shanghai, Fujian and Yunnan are always on production frontiers no matter what strategy is. So it is hard for us to measure their absolute costs. The GDP balance about Shanxi and Shaanxi is negative because of their special positions in technology set. We should analyze this situation lonely. This reflects that these two provinces, especially Shanxi, emphasize on economic development but pays limited attention to CO_2 control. From another point of view, it also indicates the economic development relies heavily on CO_2 emissions carrying in such areas, and it is a typical development mode at the cost of environmental pollution.

Other provinces have their positive CO_2 reduction costs while Beijing is the highest and Jiangsu is the lowest. The special status of political and economic and the implementation of measures taken for Olympic Games may be the main reasons.

4. Summary

Marginal abatement costs of CO_2 are important for policy-makers to determine carbon tax rate, price subsides and other related polices. With the framework of nonparametric method, a marginal abatement costs model is established, and empirical results about China in 2007 are found. The two strategies, maintaining the level of CO_2 or reducing CO_2 and expanding GDP at the same time, impact potential GDP greatly. 143.5 millions CO_2 reduction means 35.1billions GDP loss and the marginal abatement cost of CO_2 in China is 475.3yuan/ton on average.

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