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## Research on Provincial Shadow Price of Carbon Dioxide in China's Iron and Steel Industry

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### Abstract

According to the two thoughts on research of CO<sub>2</sub> emission abatement cost – as one of the inputs into the production function model or as the undesirable output into the production function model, this paper introduced China's iron and steel industry CO<sub>2</sub> shadow prices were estimated respectively in 2010-2014. The results showed that: (1) there was a big difference of CO<sub>2</sub> emission abatement cost in each region of China. The shadow price in eastern coastal area was significantly higher than that of other eastern provinces, and the shadow price in eastern province was higher than that of the central provinces and western provinces. (2) The iron and steel industry CO<sub>2</sub> shadow price in most provinces presented the downward trend year by year. (3) The shadow price estimated is much higher than China's seven pilot trading price of the carbon market. Therefore, in this paper, it is recommended that the government should consider the differences between regions and the reduction technology and experience mutually with formulating carbon trading price and related policies.

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*Keywords:* iron and steel industry; shadow price; the trans-log production function model; the directional distance function approach model

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### 1. Introduction

In the "Twelfth five-year" period, China has built the world's most complete iron and steel industry chain system, which provided most of the iron and steel materials for the national economy. At the same time, the iron and steel industry was facing with the issue of excess capacity contradictions, insufficient innovation and development ability, enhanced energy constraints to the environment and continuing difficulty of business operations. Especially a large

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area of haze weather has brought huge environmental and public opinion pressure, which has forced the government to take more stringent industry policies and environmental protection measures in iron and steel industry. In the "Thirteenth five-year" period, China's economic development will enter the crucial stage of all-round supply side structural reform. The iron and steel industry should insist on innovation drive and green development, and should realize the comprehensive and stable standards of energy consumption and pollutant emissions. Therefore, the analysis of CO<sub>2</sub> emission abatement cost in iron and steel industry can provide the establishment for regional emission reduction policies and future carbon trading price.

According to the marginal productivity theory and related definitions of shadow price, this paper defines the carbon shadow price. In the case of other inputs constant, a unit of CO<sub>2</sub> emissions reduction corresponding to the actual reduction of the total industrial output value. It can provide reference for the cost budget. It can be applied to carbon emissions trading market price subsidies and tax rates public policy as well. At present, the study of shadow price is based on two mainstream thoughts. The first thought is to take the carbon emissions as one of the inputs into the production function model, such as Lu [1], Mohtadi [2], Zhou and Du [3], etc. The second thought is to take CO<sub>2</sub> emission as the undesirable output into the production function model, such as Chen[4], Liu [5], Chen [6] and Zhou, etc. [7]. Most research on the shadow price were focus on the difference between national overall CO<sub>2</sub> marginal cost and regional CO<sub>2</sub> marginal cost, while the research for view of provincial iron and steel industry carbon emissions were quite few. At the same time, the large amounts of CO<sub>2</sub> produced in the process of industrial productions bound to cut steel production and reduce the economic output. Therefore, carbon emissions intensity decline must combine the consideration of both CO<sub>2</sub> emissions and economic benefits.

The remaining portion of the paper is organized in two parts. The first part calculates two methods of the shadow price of iron and steel industry. General conclusion can be obtained with the horizontal and vertical analysis. Finally, the second part suggesting the policy for China's iron and steel industry according to the analysis.

## 2. Methodology

- The trans-log production function model

In the present research, the production function mainly has three kinds: Cobb-Douglas production function, the constant elastic production function and trans-log production function model. Cobb-Douglas production function is mainly suitable for only the situation of a single output and two inputs. However, Cobb-Douglas production function has a very strong assumption that the elasticity of substitution is 1. If the elasticity of substitution inputs is not 1, the function will fail, which will make the estimation results biased. The constant elasticity production function is the normal form of the Cobb-Douglas production function without the elasticity limit. The constant elasticity production function is non-linear. Therefore, the parameters estimation becomes more difficult. The trans-log production function model is a kind of variable elastic production function model. The function not only includes the logarithmic term of every input, but also includes the cross terms of inputs and the square items of input. Compared with the former two kinds of function, there is higher flexibility in the replacement and transformation. Also there are no additional restrictions in technological progress, which shows a stronger applicability and reliability. Therefore, in this research the trans-log production function is used to describe the function relationship between input and output.

In this paper, the CO<sub>2</sub> emissions are considered as the third input index, and the economic output is the single output. After taking logarithm for all variables, we can establish the logarithm production function model as follows:

$$\begin{aligned} \ln Y_t = & \alpha_K \ln K_t + \alpha_L \ln L_t + \alpha_E \ln E_t + \alpha_{KL} \ln K_t \ln L_t + \alpha_{KE} \ln K_t \ln E_t \\ & + \alpha_{LE} \ln L_t \ln E_t + \alpha_{KK} (\ln K_t)^2 + \alpha_{LL} (\ln L_t)^2 + \alpha_{EE} (\ln E_t)^2 + \varepsilon \end{aligned} \quad (1)$$

$\ln Y_t$  is the logarithm of economic output,  $\ln K_t$  is the logarithm of capital stock,  $\ln L_t$  is the logarithm of labour force.  $\ln E_t$  expresses the logarithm of CO<sub>2</sub> emissions.  $\ln K_t \cdot \ln L_t$  is the cross term of the capital stock and labour force.  $\ln K_t \cdot \ln E_t$  is the cross term of the capital stock and CO<sub>2</sub> emissions.  $\ln L_t \cdot \ln E_t$  is the cross term of labour force and CO<sub>2</sub> emissions.  $(\ln K_t)^2$  is in the square item of the logarithm of the capital stock.  $(\ln L_t)^2$  is in the square item of the logarithm of labour force.  $(\ln E_t)^2$  is in the square item of the logarithm of CO<sub>2</sub> emissions.  $\varepsilon$  is the random error term. Then we can get:

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