A Model of Economic Output Valuation for Carbon Emission Enterprises Based on Markov Chain in the Context of Economic Growth

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ABSTRACT: The extended Cobb-Douglas production function is used based on the transition probabilities matrix with reflecting wall and absorbable wall determined by the non-homogeneous Markov chain. According to the current number ratio of various types of enterprises under different carbon emission conditions, the number ratio of various enterprises after the multi-stage carbon unlocking evolution transfer process is determined. And finally the economic output of different types of enterprises under different carbon emission conditions and the corresponding valuation model are determined.

KEYWORDS: Non-homogeneous Markov chain; Extended Cobb-Douglas function; economic output valuation model.

1 RESEARCH BACKGROUND
Global warming caused by carbon dioxide emissions has attracted growing concern in the world, the unlocking between carbon emissions and economic growth is the inevitable trend of the future development. Under the conditions of carbon unlocking evolution transfer at different stages, the estimation of the economical output in different carbon emissions industrial enterprises is of great practical significance to promote industrial carbon unlocking and structural optimization.

2 THEORY AND MODEL
The Cobb-Douglas function is a function indicating the relationship between economic factors and economic output. The extended Cobb-Douglas function is established by adding the factor of the average level of carbon dioxide emissions, and carbon emissions is correlated with economic output. Then, according to the decoupling model of Lu Zhongwu, Wang Heming and Yue Qiang, the states of non-homogeneous Markov chains under economic growth and the transfer rule are determined; also, the transition probability matrix of the carbon unlocking evolution process is obtained. Then, according to the number ratio of enterprises with different market emission conditions in the fixed-term, the number ratio of the enterprises with different emission conditions after carbon unlocking evolution in variable period is calculated. Finally, the economic output of enterprises with different carbon emission conditions in different periods is calculated and the model is established. The model involves six elements: average level of carbon dioxide emission, extended Cobb-Douglas function, decoupled state, Markov chain, transition probability matrix, and economic output valuation.

2.1 Average level of carbon dioxide emissions
Carbon emissions enterprises always emit carbon dioxide in the production and operation, for the average level of carbon dioxide emissions, its specific formula is as follows:

$$MCO_2 = \frac{\sum_{i=1}^{n} \sum_{t=1}^{44} (MCO_2)_i}{n}$$

$$= \frac{\sum_{i=1}^{n} \sum_{t=1}^{44} [ME_i \times MNCV_i \times MUCEF_i \times MCOF_i \times (44/12)]}{n}$$ (1)

$MCO_2$ is the average emissions of carbon dioxide in all regions at the n-th period, $(MCO_2)_i$ is the average emissions of carbon dioxide in the i-th region at the t-th period, $ME_i$ is the average energy consumption in the i-th region at the t-th period, $MNCV_i$ is the average low calorific value of all energy in the i-th region at the t-th period, $MUCEF_i$ is the average utilization coefficient of all energy in the i-th region at the t-th period, and $MCOF_i$ is the average cost of carbon in the i-th region at the t-th period.
2.2 The extended Cobb-Douglas production function

The Cobb-Douglas function is a function indicating the relationship between economic factors and economic output. The average CO₂ emission level is added as the third factor while preserving capital stock and labor input to express the relationship between carbon emission and economic output, and its function is as follows:

\[ Y_a = A_a K_a^{\alpha(i,t)} L_a^{\beta(i,t)} (MCO_2)^{\gamma(i,t)} \]  

(2)

\( Y_a \) refers to the economic output in the i-th region at the t-th period. \( A_a \) refers to the technique level in the i-th region at the t-th period. \( K_a \) indicates the capital stock in the i-th region at the t-th period, \( L_a \) indicates the labor input in the i-th region at the t-th period, \( (MCO_2) \) indicates the average carbon dioxide emissions in the i-th region at the t-th period, \( \alpha(i,t) \) indicates the elasticity coefficient of capital to output in the i-th region at the t-th period, \( \beta(i,t) \) indicates the elasticity coefficient of labor to output in the i-th region at the t-th period, and \( \gamma(i,t) \) indicates the elasticity coefficient of carbon dioxide emissions to output in the i-th region at the t-th period. Assuming the returns to the scale of production to be constant, \( \alpha(i,t) + \beta(i,t) + \gamma(i,t) = 1 \), \( A_a = f(FDI_H, H, FDI_H \times H) \), foreign direct investment \( FDI \) in the aspect of environmental protection and human capital level are introduced \( H \) are introduced to produce spillover effect, improve the environmental protection technology level of enterprises.

2.3 Decoupled state

According to the decoupling model based on IPAT equation proposed by Lu Zhongwu, Wang Heming and Yue Qiang, there are 3 decoupling states shown as in Table 1:

If carbon dioxide emissions increase with the same speed or even faster than economic growth, there is a coupling between the two, namely, economic growth and carbon dioxide emissions are not decoupled; if the growth rate of carbon dioxide emissions is less than the magnitude of economic growth, it is called relative decoupling; if carbon dioxide emissions continue to decline as the economy grows, it is called absolute decoupling. The relationship between economic output and carbon emissions of the carbon emission enterprises can also be applied to the model.

Table 1. The corresponding relationship between the decoupling index and the decoupling state.

<table>
<thead>
<tr>
<th>Decoupling State</th>
<th>Decoupling Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Decoupling</td>
<td>(−∞, 0]</td>
</tr>
<tr>
<td>Relative Decoupling</td>
<td>(0,1)</td>
</tr>
<tr>
<td>Absolute Decoupling</td>
<td>[1, +∞)</td>
</tr>
</tbody>
</table>

At present, only the three carbon emission states under the condition of economic growth are studied, that is, no decoupling, relative decoupling, and absolute decoupling.

2.4 Markov chain

The no decoupling state is denoted by 0, the relative decoupling state is denoted by 1, and the absolute decoupling state is denoted by 2. Wherein, each of the two neighboring states can be transferred to each other, when the state is not decoupled, it must be transferred to the relative decoupling state by 100%, when in absolute decoupling state, it will not be transferred. In accordance with the carbon unlocking process, it is from no decoupling to relative decoupling, and then from the relative decoupling to absolute decoupling. Because the transition probabilities are different in different periods, a non-homogeneous Markov chain can be constructed according to the transfer rule, as shown in Fig 1.

Figure 1. A non-homogeneous Markov chain at the state of carbon emission at different time in different regions.

2.5 Transition probability matrix

Wherein, 0 is the reflective wall, and 2 is the absorbable wall, the transition probability matrix of the t-th period is:
According to the transfer rules, then

\[
M_i = \begin{bmatrix}
0 & 1 & 0 \\
0 & 0 & 1 \\
0 & 0 & 0 
\end{bmatrix}
\]

(4)

\( \eta_i \) refers to the ratio of cumulative difference of average carbon dioxide emissions in all regions in the subsequent period and the current period to cumulative emissions average carbon dioxide in all regions in the current period. Then take the absolute value, the expression is as follows:

\[
\eta_i = \left| \frac{\sum_{i=1}^{n}(MCO_2)_{i+1} - \sum_{i=1}^{n}(MCO_2)_{i}}{\sum_{i=1}^{n}(MCO_2)_{i}} \right|
\]

(5)

When \( \sum_{i=1}^{n}(MCO_2)_{i+1} = 0 \), that is, complete carbon unlocking is achieved, carbon dioxide is not completely emitted at this time, so \( \eta_i = 1 \), then

\[
M_i = \begin{bmatrix}
0 & 1 & 0 \\
0 & 0 & 1 \\
0 & 0 & 0 
\end{bmatrix}
\]

At this time, the relative decoupling state can be 100% converted to the absolute decoupling state at the time of transition.

2.6 The economic output valuation

Assuming there are only three types of enterprises of no decoupling, relative decoupling, absolute decoupling in the current market, each enterprise respectively accounts for the total number of enterprises of \( \theta_0(t) \), \( \theta_1(t) \) and \( \theta_2(t) \), then assuming \( S_i = [\theta_0(t), \theta_1(t), \theta_2(t)] \), if it is calculated from the g-th period, the step transition probability matrix of \( h-g \) \( (h > g, 1 \leq g < h \leq n, h, g \in N^+ \) \) at the end of the h-th period is:

\[
M_{i(h-g)} = \begin{bmatrix}
0 & 1 & 0 \\
0 & 0 & 1 \\
0 & 0 & 0 
\end{bmatrix}
\]

(7)

Assuming \( M_{i(h-g)} = [\varphi_{11}, \varphi_{12}, \varphi_{13}] \), \( \varphi_{21}, \varphi_{22}, \varphi_{23} \)

\[
M_{i(h-g)} = \begin{bmatrix}
\varphi_{11} & \varphi_{12} & \varphi_{13} \\
\varphi_{21} & \varphi_{22} & \varphi_{23} \\
\varphi_{31} & \varphi_{32} & \varphi_{33} 
\end{bmatrix}
\]

(3)

Similarly, the ratio of relative decoupling and absolute decoupling enterprises accounted for the total number of enterprises:

\[
r_i = S_i \times M_{i(h-g)} = \begin{bmatrix}
\varphi_{11} \\
\varphi_{12} \\
\varphi_{13} 
\end{bmatrix}
\]

(9)

\[
r_i = S_i \times M_{i(h-g)} = \begin{bmatrix}
\varphi_{21} \\
\varphi_{22} \\
\varphi_{23} 
\end{bmatrix}
\]

(10)

Wherein, \( r_0 + r_1 + r_3 = 1, \theta_0(t) + \theta_1(t) + \theta_2(t) = 1 \)

The economic output at the i-th region in the h-th period is \( Y_{i(h-g)} = A_{h}K_{i(h-g)}L_{i(h-g)}(MCO_2)_{i(h-g)} \), then the economic output valuation contributed by the absolute decoupling enterprises at the i-th region in the h-th period is:

\[
\hat{Y}_i(2) = Y_{i(h-g)} \cdot r_2
\]

(11)

The economic output valuation contributed by the relative decoupling enterprises:

\[
\hat{Y}_i(1) = Y_{i(h-g)} \cdot r_1
\]

(12)

The economic output valuation contributed by the no decoupling enterprises:

\[
\hat{Y}_i(0) = Y_{i(h-g)} \cdot r_0
\]

(13)

With the above six factors, the economic output valuation model of different carbon emission enterprises in different regions can be constructed.

3 THE ECONOMIC OUTPUT VALUATION MODEL

After the \( h-g \) period, the economic output
valuation matrix contributed by three different enterprises in the i-th region is:
\[
\hat{Y}_i = \begin{bmatrix}
Y_{i(0)}
& Y_{i(1)}
& Y_{i(2)}
\end{bmatrix}
\] (14)

After the \(h-g\) period, the economic output valuation matrix contributed by three different enterprises in different regions is:
\[
\hat{Y} = \begin{bmatrix}
Y_{i(0)}
& Y_{i(1)}
& Y_{i(2)}
& \cdots

Y_{m(0)}
& Y_{m(1)}
& Y_{m(2)}
& \cdots
\end{bmatrix}
\] (15)

\(\hat{Y}\) is the corresponding economic output valuation model, the expression of the model is a matrix.

4 CONCLUSIONS

The economic output valuation model can estimate the contribution of the three kinds of carbon emission enterprises in three kinds of carbon emission enterprises of regional economic output volume under the conditions of different carbon emissions, namely, no decoupling, relative decoupling and absolute decoupling. Through the relevant carbon emission states and economic output, the enterprise carbon unlocking process in the corresponding regions can be monitored, so as to promote energy saving and emission reduction and optimization and adjustment of production structure and accelerate the decoupling process between the economic growth contributed by carbon emission enterprises and carbon dioxide emission volume, and ultimately achieve environmental protection and reliable corporate behavior under the conditions of economic growth. By attracting foreign direct investment, the implementation of the connotative expansion, and the enterprise efficiency of energy saving and emission reduction is promoted by the means of technological innovation and other methods.

REFERENCES