The Potential Energy of Carbon Resources Flow in Industrial System under the Restriction of Carbon Quota:A Research Based on Biased Technological Progress

Zheng-Nan Lu, Dong-Dan Zhu, and Jian Wang

***Abstract*—Under the background of the national unified carbon market is about to be established, the industrial system of our country is faced with the decision reducing production, proving technology or purchasing carbon quota. Starting from the bias of technological progress in the industrial sector , this paper is point of penetration with the technological progress to expound the bias of technological progress will lead that carbon resources among the industrial sectors has the "potential energy" flowing from one industry sector to another with the actual data of China's, which demonstrates the implementation of carbon quota will make the carbon resources flow in the industrial sector, driving the evolution of low-carbon. Using DEA-Malmquist index decomposition method, we get the conclusion: (i)there is technical progress bias in China's industrial system, and which has a gain effect on productivity; (ii)the technical progress bias is sTable in China's industrial system; (iii)The technological progress of China's industrial system is partial to carbon resource saving; (iv)with the help of the cross coordinates, we get the results that: the technical progress bias carbon resources saving in 9 industrial sectors, which does not exist in the other 2 industries. That demonstrates the "potential energy" of carbon resources flowing; (v)the technological progress has made the whole industrial system biasing towards carbon resource saving, and the industrial system is gradually optimized.**

***Index Terms*—Biased technological progress, carbon flow, decomposition of DEA-malmquist index, industrial system, potential energy.**

I. Introduction

Under the background of energy conservation and emission reduction has become a global consensus, in October 2011, the National Development and Reform Commission released the Notice on Carrying out the Work of Carbon Emission Trading Pilot Program, which approved seven municipalities and provinces to launch the ETS pilot, including Beijing, Tianjin, Chongqing, Hubei, Guangdong and Shenzhen. China has become the second largest carbon trading system after the European Union, and will comprehensively set up carbon trading market in 2017. It is ineviTable that carbon quota is carried out in our country. Under the constraint of carbon quota, the development of China's industrial system is in a bottleneck period： there have been the industrial growth heavily depend on energy consumption and the industrial system emissions reduction constraints on the industrial dynamic optimal operation. It is an urgent problem to be solved that to make clear of the low-carbon evolution mechanism of industrial system and to guide it with effective policies. That also has important practical significance.

After the full implementation of carbon quota, the industrial sectors face the following four options: (i) cutting carbon emission by reducing production; (ii) actively investing capital to research and development to promote technological progress, so as to reduce carbon emissions; (iii) cutting carbon emission by purchasing technology; (iv) buying carbon quota to meet the need of production. Starting from the bias of technological progress in the industrial sector, this paper is point of penetration with the technological progress to expound the bias of technological progress will lead that carbon resources among the industrial sectors has the "potential energy" flowing from one industry sector to another with the actual data of China's, which demonstrates the implementation of carbon quota will make the carbon resources flow in the industrial sector, driving the evolution of low-carbon.

II. The Influence of Technological Progress on the Flow of Carbon Resources

Through combing the literature at home and abroad, this paper argues that technological progress is an important factor in reducing carbon emissions and mitigating the carbon resource consumption, to a certain extent, improving the efficiency of the use of carbon resources and reducing carbon emissions intensity. Wang [1] pointed out that technological progress should be the main means to realize carbon emission reduction and reduce the intensity of carbon emission in China. According to the principle of economics, technological progress changes the marginal productivity of carbon resource, capital, and labor, predisposing the technological progress to different factors conservation, which constitutes the feature of technological progress bias. Market mechanism is the specific cause of the deviation of technological progress. Market mechanism evokes the technical progress bias. The bias of technological progress will eventually determine that the "potential energy" of carbon resources differs in industrial sectors. It is not only the

Manuscript received December 29, 2016; revised April 20, 2017. This work was supported by National Science Council of China (contract No. 71673120) and Ministry of Education of China (contract No. 16YJA630035).

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doi: 10.18178/joebm.2017.5.4.509

promise for the flow of carbon resources, but also the basis of industrial system entropy reduction.

A. The Characteristic of the Biased Factor Allocation in Technological Progress

The economist Hicks [2] proposed that technological progress can change marginal productivity (MP) in the same ratio between production factors, that is called technical progress neutral. It also can change the marginal rate of substitution (MRS) between the different elements, which is called the technical progress bias. We commonly referred to the latter as biased technical progress (BTC). Biased technological progress could change the marginal rate of substitution, which means that it can also change the input ratio between carbon resources and other factors, that will have an important impact on the carbon emissions of China's industrial sector. Under the constraint of the carbon quota, it can be envisaged that if the technological progress of an industrial sector bias to conservation of carbon resources, the sector will better achieve carbon emissions reduction. Therefore, with the relevant actual data of China's industrial sector, this paper will study an important question: whether there is bias of technological progress of carbon resource saving in China's industrial sector. If it is, after carbon quotas fully implementing, the tendency of carbon resource consumption will change in industry departments. The bias of technological progress makes the limited carbon resource flowing in the industrial sectors. After the implementation of carbon quota, it is the basis of optimizes the operational efficiency of industrial system to explore the technological progress and the flow of carbon resources.

B. The Induced Mechanism of Technological Progress Bias

Wang [3] pointed out that the main factor impacting the bias of technological progress is the the price effect and the market scale effect. And the price effect has an effect on the bias of technological progress from the perspective of scarce resources. Special scarce resources play an indispensable role in the industrial sector to achieve economic growth and breakthrough factor endowments constraints. Technology imports and R&D in industry sector , to a certain extent, are to increase the production efficiency of scarce resources, so as to conserve scarce resources. This shows that the technical progress bias saving expensive and indispensable resources. Which is called price effect. From expanding the input scale of production factors to output efficiency improvement, the efficiency of production factors gets considerable improvement, in which technological progress plays a key role. Because the technical progress and the input of production factors are well-matched, which is beneficial to productivity. In short, the price effects makes technological progress bias scarce resources, but the market scale effect makes technological progress in favor of abundant resources. Sufficient resources ultimately feel industry technical progress bias characteristics is the result of comprehensive effect of price and market scale effect, is the elasticity of substitution between scarce resources and abundant resources. Finally, the characteristic of technological progress depends on the comprehensive result of price effect and market scale effect, also the elasticity of substitution between the scarce resources and abundant resources. The deep reasons for existing the price effect and the market size effect is the characteristics of scarce resources and abundant resources. From the point of view of market, if one kind of product's trade is frequent, it lacks of scarcity and is easy to be replace. On the contrary, the trade frequency of one kind of product is low, then it is more scarce and less alternative. Furthermore, the level of product technology is also an important factor affecting the scarcity and substitutability. These factors, to a large extent, affects the characteristics of technical progress bias. In addition, a number of nonmarket factors also affect the characteristics of technological progress bias, including the external economic environment, government policies, producer heterogeneity and consumer heterogeneity. These factors also have an effect on the production factors' scarcity and substitutability, so that affect the price effect and the market size effect, and ultimately affect the bias of technological progress. Fig. 1 shows that process.

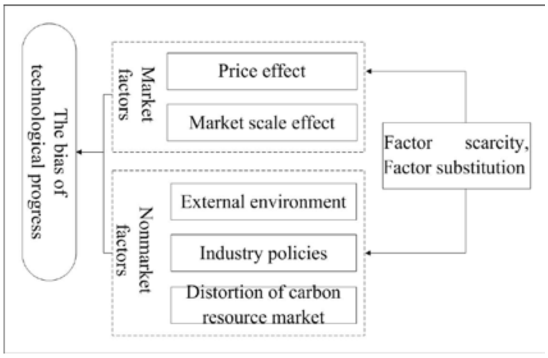

Fig. 1. The influencing factors and mechanism of the characteristics of technological progress bias.

In conclusion, the characteristics of biased technological progress will be affected by the market factors, mainly the price effect and the market size effect. Besides, the characteristics of biased technological progress will be affected by non-market factors, mainly including the macro environment, industry policy and the impact of market distortions caused by the heterogeneity of producers and consumers.

C. The Characteristics of Biased Technological Progress Decides to the "Potential Energy" of Flowing Carbon Resources

After the full implementation of carbon quota, the industrial sectors face the following four options: (i) cutting carbon emission by reducing production; (ii) actively investing capital to research and development to promote technological progress, so as to reduce carbon emissions; (iii) cutting carbon emission by purchasing technology; (iv) buying carbon quota to meet the need of production. The difference in bias of technological progress is an important influencing factor in choosing to reduce output, lift technique, or purchase quotas [4] . we study "potential energy"of carbon resource by analogy with potential energy in physics. The industrial sector's demand for carbon resources is different because of their different technical bias. Part of the industrial sectors which own high level technology, their technical progress biases other capitals, resulting in the use of carbon resources have a downward trend. After the implementation of carbon quota policy, carbon resources on the impulse to flow to other industries. This "impulse" can be expressed by the "potential energy" of the carbon resources.

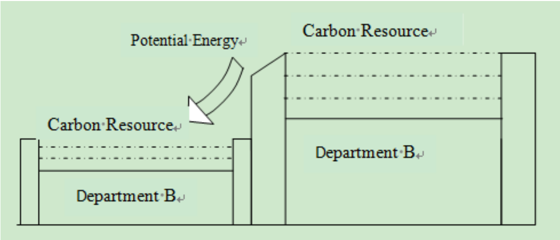

Fig. 2. Potential energy of carbon resource flows among industry sectors.

III. Calculating the Bias of Technical Progress

On the measurement of technological progress, according to the R&D input and the technology from cumulative R&D input, Li *et al.*, [5] measured the size of the technological progress with metering method. In the field of economics, total factor productivity (TFP) generally represents the performance of technological progress based on the production function. Departments whose technology progress bias carbon resource conservation, have different marginal rate of substitution between carbon resources and other capital. Therefore, it is a more appropriate method to analyze the bias of technical progress that the production function is used to calculate the TFP. According to Fare *et al.* [6], the IBTECH index was used to study the biased technical progress of capital-saving and labor-saving. Considering carbon resources input, using IBTECH index to analyze the bias of technical progress in China's industrial sector. On the basis of whether or not existing biased technological progress of carbon resources saving, to analyze the technical bias of different industrial sectors. By proving that the carbon resource among the departments has the "potential energy", the "half-hoop" of the low carbon evolution spiral is confirmed.

A. The Difference between TFP's Decomposition Method and Transcendental Logarithmic Cost Function Model

Solow is the earliest person proposing TFP. When calculated the total output production function, he obtained the equation expression form of growth rate of total output, and put forward TFP is that the growth rate of total output deduct the contribution of capital and labor, called solow residue. Based on total factor productivity, the partial index of technological progress must be estimated, and the elasticity of substitution and the efficiency of the essential factors must be estimated. It is necessary to estimate the elasticity of substitution and the efficiency of the elements so that decomposing TFP into the index of technical progress bias partial. There are some mature methods. Based on the fixed elasticity of substitution CES model, Klump *et al.* [7] studied the factor efficiency of the industrial sector from the supply side in the United States. Lei *et al.* [8] studied the bias of technical progress and TFP by using the decomposition method of TFP.

Different from TFP decomposition method, Translog Production Function (TPF) without a fixed elasticity of substitution, more fully reflects the interaction and effect of substitution between the factors of production [9]. In the process of studying the bias of technological progress about China's manufacturing innovation, Yang [10] pointed out that we could add the factor of time into the TPF, which will reflect the differences of technical progress coming from production factors input in different stages. That better reflects the connotation of the development of industrial systems. However, until now, in the research of technical progress bias, the research of putting other factors (such as carbon resource) into TPF is still not mature besides capital and labor factors. So this paper studies the biased technological progress of carbon resource conservation in China's industrial system based on TFP decomposition.

B. The Index of Technical Bias based on DEA-Malmquist Index Decomposition

This paper uses DEA-Malmquist index to calculate TFP, which was proposed by Fare *et al*. [11]. Fare *et al*. combined Malmquist index, non-parametric linear programming method with data envelopment analysis (DEA) theory, so that the Malmquist index has been widely used in the field of production efficiency measurement [12].

DEA-Malmquist index can be decomposed into technical change index (TECH) and technical efficiency change index (EFFCH) , which is used to reflect the change of production frontier and the distance between combination of input factor and production frontier. They still can not reflect technological progress bias well. So Fare *et al*. continued to decompose the TECH index into technical scale change index (MATECH), output bias index (OBTECH) and input bias index (IBTECH). The IBTECH index is the technical progress bias index of input factor saving, which is studied next step.

The TECH was decomposed as:

$$MATECH = \frac{D_0^{t+1}(y^t, x^t)}{D_0^t(y^t, x^t)} \tag{1}$$

$$OBTECH = \sqrt{\frac{D_0^{t+1}(y^{t+1}, x^{t+1})}{D_0^t(y^{t+1}, x^{t+1})} / \frac{D_0^{t+1}(y^{t+1}, x^t)}{D_0^t(y^{t+1}, x^t)}} \tag{2}$$

$$IBTECH = \sqrt{\frac{D_0^{t+1}(y^{t+1}, x^t)}{D_0^t(y^{t+1}, x^t)} / \frac{D_0^{t+1}(y^t, x^t)}{D_0^t(y^t, x^t)}} \tag{3}$$

MATECH represents the neutral technology progress and the translation of the production frontier.

OBTECH represents the technological progress bias of output, and technology progress enhancement effect of different proportion of output.

IBTECH represents the technical progress bias of input factors, and reflects that the change of marginal rate of substitution has effect on the technological progress between input factors.

C. Judging Methods of Technological Progress Bias

IBTECH measures the enhancement effect or reducing effect of technological progress on TFP. But the research of Fare ET al. does not give the certain direction of technical progress bias. In order to further explore the technological progress bias between the input factors, Weber & Domazlicky [13] and Wang Banban & Qi proposed different combination of $IBTECH$ and 1 based on the different period, then measured the bias of technological progress.

When the input variables include 3 elements, according to the comparison of the elements each year and the IBTECH index, the judge of the technical progress bias shown in Table I.

TABLE I: THE JUDGE OF THE TECHNICAL PROGRESS AS BIAS

	$IBTECH > 1$	$IBTECH < 1$
$(x_1/x_2)^{t+1} > (x_1/x_2)^t$	x_1 saving and x_2 input under the technology progress	x_1 input and x_2 saving under the technology progress
$(x_1/x_2)^{t+1} < (x_1/x_2)^t$	x_1 input and x_2 saving under the technology progress	x_1 saving and x_2 input under the technology progress
$(x_1/x_3)^{t+1} > (x_1/x_3)^t$	x_1 saving and x_3 input under the technology progress	x_1 input and x_3 saving under the technology progress
$(x_1/x_3)^{t+1} < (x_1/x_3)^t$	x_1 input and x_3 saving under the technology progress	x_1 saving and x_3 input under the technology progress
$(x_2/x_3)^{t+1} > (x_2/x_3)^t$	x_2 saving and x_3 input under the technology progress	x_2 input and x_3 saving under the technology progress
$(x_2/x_3)^{t+1} < (x_2/x_3)^t$	x_2 input and x_3 saving under the technology progress	x_2 saving and x_3 input under the technology progress

IV. COLLECTION AND CALCULATION OF RELEVANT DATA

This paper uses the panel data of China's 39 industrial sectors in 2001-2014 years to carry out regression analysis. The data comes from industrial enterprises above designated size. Which is from the primary sources including *China Statistical Yearbook*, *China Labor Statistics Yearbook*, *China Industrial Statistical Year Book* and *Statistical Yearbook of China's Carbon Resources*.

A. The Input and Price of Carbon Resources

For calculating China's carbon intensity, we refer to the data for each year from *China Statistical Yearbook*. The ready-made CO2 emissions data can not be found, so we calculate them with the date of fossil energy consumption.

$$C_i = \sum_{j=1}^{n} \delta_j N_{ij} \quad (4)$$

C_i is the CO2 emissions coming from the *ith* sector; N_{ij} is the jth energy consumption in the *ith* industry sectors; δ_j is the coefficient of carbon dioxide emissions of the *jth* energy; The calculation formula of carbon dioxide emissions coefficient is as follows [14]:

$$\text{Carbon dioxide emissions coefficient} = \frac{44}{12} * \text{Average low calorific value} * \text{Carbon content per calorific value} * 10^{-6} * \text{Carbon oxidation rate} * 10^{3} \quad (5)$$

B. Capital Input

In this paper, the capital (K) input references Wang, who used capital stock data of industrial sectors. Calculating capital stock from 2001 to 2014 to with the perpetual inventory method. The specific means is:

$$K_{it} = K_{it-1}(1-\delta_{it}) + I_{it} \quad (6)$$

C. Labor Input

The labor (L) input of this paper is the annual average workers in the various sectors, whose data is from *China Statistical Yearbook* and *China Industrial statistical yearbook.*

D. The Raw Materials Input and Price

The raw material (M) input cannot be directly obtained from the statistical yearbook, but the cost of raw material is included in the cost of main business. According to the definition, main business cost includes the cost of raw material, labor cost and manufacturing cost. Main business cost, labor cost and manufacturing cost can be obtained in the industrial economic statistical yearbook, so the raw material input data can be gained [15].

E. Technical Progress

In this paper, the relevant data of technical progress references Li's, including the cumulative level of technical progress (T) and new R&D input (R). Factors such as the depreciation rate and absorption rate are calculated. The specific formula is as follows:

$$T_t = \mu T_{t-1} + vR \tag{7}$$

V. The Empirical Study of Carbon Resource Flowing Trend based on Technical Progress bias

By virtue of the testing formula of technical progress bias, and making use of the data of 39 China's industrial sectors from 2001 to 2014, the IBTECH index can be calculated which includes four input elements: Capital (K), Labour (L), Carbon resources (C) and Raw materials (M).

In order to calculate these indicators, DEA method was used to calculate these distance functions [16]. For each DMU k' (it represents each industrial sectors in this paper), diatance functions can be Fig.d out by Liner programming (LP). Following are relevant hypothesise and mathematic models.

$$[D_0^{t+i}(x_{k'}^{t+j}, y_{k'}^{t+q})]^{-1} = \max_{\theta, z_k^{t+i}} \theta^{k'}$$

s.t.:

$$-\theta^{k'} y_{k',m}^{t+q} + \sum_{k=1}^{K} z_k^{t+i} y_{k,m}^{t+i} \geq 0, m = 1, 2, \cdots\cdots M \tag{8}$$

$$x_{k'}^{t+j} - \sum_{k=1}^{K} z_k^{t+i} x_{k+n}^{t+j} \geq 0, n = 1, 2, \cdots\cdots N$$

$$z_k^{t+i} \geq 0, k = 1, 2, \cdots\cdots K$$

In the LPs above, there are 6 distance functions concerned with index calculating. $[D_0^t(x_{k'}^t, y_{k'}^t)]^{-1}$ was calculated by $(i, j, q) = (0, 0, 0)$, $[D_0^{t+1}(x_{k'}^{t+1}, y_{k'}^{t+1})]^{-1}$ was calculated by $(i, j, q) = (0,1,1)$, $[D_0^{t+1}(x_{k'}^t, y_{k'}^{t+1})]^{-1}$ was calculated by $(i, j, q) = (1,0,1)$,

$[D_0^{t+1}(x_{k'}^{t+1}, y_{k'}^t)]^{-1}$ was calculated by $(i, j, q) = (1,1,0)$, $[D_0^{t+1}(x_{k'}^t, y_{k'}^t)]^{-1}$ was calculated by $(i, j, q) = (1, 0, 0)$. Moreover, N represents for sample amount of output elements, M' represents for sample amount of output, K' represents for sample amount of industrial, θ is a vector set of output. z_k^{t+i} is an intensity variable, which means production intensity of producing k .

A. The Accomplishment of Technical Progress bias Model based on Malmquist Index

This paper makes use of Benchmarking program package in R language, and did an empirical calculating for distance function of each index. After that, calculating Malmquist index and its decomposition, and malmquist function of FEAR program package in R language was used to calculate and demonstrate Malmquist index. Calculated data were showed in Table II.

Furthermore, this paper also calculated the whole technical progress bias index of 39 industrial sectors from 2001 to 2014, as well as the period of "the 11th Five-Year Plan" "the 10th Five-Year Plan." So that deeply studying China's industrial system technology bias in different periods. Whose data was also showed in Table II.

B. Ananlysis of Malmquist Index Decomposition in China's Industrial Sectors

1) There is technical progress bias in China's industrial system, which offers gain effect to productivity

In Table II, the value of $IBTECH$ of all industrial sectors were few bigger than 1 from 2001 to 2014, which means each China's industrial sector have obvious technical progress bias, and it produced gain effect to industrial sector. Analyzing $IBTECH$ index of 39 industrial sectors year by year, we found their average value are bound to greater than 1. This outcome indicated that the feature of technical improvement preference had a positive influence on gain effect for China's industrial sectors from 2001 to 2014 [17]. In addition, outcomes of Table 2 also illustrated, in the period of 2001-2014, "the 11th Five-Year Plan", "the 10thFive-Year Plan", $IBTECH$ index also >1, which strongly supported the conclusion that "there is technical progress bias in China's industrial system and it has gain effect on productivity".

2) Chinese industrial system preference has a steady feature

Analyzing every value of $IBTECH$ index in Table II, we discovered that all $IBTECH$ index were bigger than 1, though it was not a big increase, it was steady. Comparing every TFP index of industrial sectors, we can find that the values of TFP index were somewhat fluctuate, but $IBTECH$ index is steady. The technological progress bias is one of the sTable contribution factors of TFP improvement in China's industrial sector.

C. The Trend of Technological Progress bias and Distribution of Carbon Resources in China's Industrial Sector

Through the calculation of the index in China's 39 industry sector, we can draw a conclusion that the bias of technological progress has gain effect on the TFP of industrial system. The purpose of this paper is to better understand which production factors that technical progress of China's industrial sector bias. Which also means to earn the technological progress bias of exact factors in industry sector.

Therefore, based on the calculation of $IBTECH$ index in China's industry sector and the discriminant principle of the technical progress bias put forward by Weber & Domazlicky and Wang *et al.*, then combining elements input proportion in latest two period, to analysis the technology progress bias on elements saving in China's industry sector. In this paper, we used four elements which include capital, labor, carbon resources and raw materials, to analysis the technical progress bias on carbon resource saving. So, this paper takes the result as discriminant that whether technical progress can save carbon resources between carbon resource and capital C/K, carbon resource and labor C/L, carbon resource and raw material C/M, to analysis the trend over time of technological progress in carbon resources saving and its distribution in industrial sectors [18].

TABLE II: 2000-2014 SOME INDEX ABOUT CHINA'S INDUSTRIAL SECTOR

	MALM	EC	TC	IBTC		MALM	EC	TC	IBTC
X1	1.0023	1.0004	1.0019	1.0003	X21	1.0065	1.0057	1.0008	1.0009
X2	1.0035	1.0007	1.0028	1.0015	X22	1.0354	1.0347	1.0007	1.0021
X3	1.0048	1.0012	1.0036	1.0007	X23	1.0950	1.0934	1.0015	1.0025
X4	1.0036	1.0009	1.0027	1.0008	X24	1.0402	1.0078	1.0321	1.0027
X5	1.0038	0.9979	1.0059	1.0021	X25	1.0349	1.0329	1.0019	1.0007
X6	1.0061	1.0017	1.0044	1.0015	X26	1.0751	0.9577	1.1226	1.0005
X7	1.0067	1.0021	1.0046	1.0026	X27	1.0452	1.0438	1.0013	1.0015
X8	1.0045	1.0019	1.0026	1.0009	X28	1.0311	1.0306	1.0005	1.0014
X9	1.0119	0.9993	1.0126	1.0005	X29	1.0021	1.0006	1.0015	1.0016
X10	1.0138	1.0017	1.0121	1.0013	X30	1.0345	1.0321	1.0023	1.0005
X11	1.0188	0.9962	1.0227	1.0023	X31	1.0048	1.0027	1.0021	1.0013
X12	1.0438	1.0018	1.0419	1.0021	X32	1.0437	1.0019	1.0417	1.0018
X13	1.0306	0.9978	1.0329	1.0012	X33	1.0038	1.0029	1.0009	1.0008
X14	1.0144	1.0017	1.0127	1.0009	X34	1.0381	1.0027	1.0353	1.0027
X15	1.0108	1.0079	1.0029	1.0003	X35	1.0397	1.0429	0.9969	1.0011
X16	1.0060	1.0048	1.0012	1.0015	X36	1.0029	1.0012	1.0017	1.0013
X17	1.0129	1.0012	1.0117	1.0017	X37	1.0048	1.0017	1.0031	1.0004
X18	1.0230	1.0007	1.0223	1.0031	X38	1.0698	1.0023	1.0673	1.0023
X19	1.0240	1.0021	1.0219	1.0019	X39	1.0507	1.0519	0.9989	1.002
X20	1.0175	1.0032	1.0143	1.0011					

1) The whole factor bias of technological progress in China's industrial system

Comparing the size of 1 and $IBTECH$ of China’s industrial sections in 2001-2014 years, we can find that most of $IBTECH$ is bigger or equal to 1, as shown in Fig. 3.That illustrate that the general technical progress basis tends to promote the growth of TFP in China’s industrial sector. The right part of Table 3 shows the empirical results obtained by the discrimination method of technical progress factor bias. The results show that, on the whole, the technological progress bias carbon resource conservation in China's industrial system. Detailed analysis of carbon resource and capital input, the column data of C/K in Table 3 shows that, except for the data is bigger than1 in 2002-2005, the result of the remaining 10 years’ are less than 1, shows that China's industrial system tends to save carbon resources instead of capital. The result of column data of C/L in Table 3, shows that only the value of the year 2008, 2010, 2012 and 2014 is less than 1, the rest are all bigger than 1, suggesting that China's industrial system tends to save labor instead of capital. The result of column data of C/M in Table 3 shows that the value is less than 1 from 2001 to 2014, suggesting that China's industrial system tends to save carbon resources instead of raw materials. This result is relatively consistent with Wang’s. At the same time, this result also shows that the technological progress of China's industry system promoted carbon emission reduction since 2001.

2) The deviation analysis of industry department technology progress

After analyzing the factor bias of technological progress in China’s industry system, the technological progress bias of carbon resources between different sectors will be explored continually, so that it will be clear that the bias of technological progress cause the liquidity "potential energy" of industry sector carbon resources [19].

When analyzing biased factor allocation of 39 China’s industrial department, carbon resources is part of the raw material, which belong to sectors’ intermediate input, so what is emphatically analyzed in this paper is that the bias among the capital, labor and carbon resources. With the cross coordinate method, we show them in Fig. 3.

TABLE. III: THE DISTRIBUTION OF TECHNOLOGICAL PROGRESS BIAS AND FACTOR BIAS IN CHINA'S INDUSTRIAL SECTORS

年份	IBTC			$\frac{(C/K)^{t+1}}{(C/K)^{t}}$	$\frac{(C/L)^{t+1}}{(C/L)^{t}}$	$\frac{(C/M)^{t+1}}{(C/M)^{t}}$
	> 1	<1	=1			
2001	16	7	16	0.9777	1.0543	0.9562
2002	15	7	17	1.0164	1.0443	0.9197
2003	15	7	17	1.0604	1.0901	0.9102
2004	19	6	14	1.0109	1.0139	0.9077
2005	17	7	15	1.0181	1.0624	0.9442
2006	17	7	15	0.9675	1.0287	0.9056
2007	15	6	18	0.9593	1.0137	0.8979
2008	15	7	17	0.8903	0.9308	0.8994
2009	15	7	17	0.9164	1.0682	0.9011
2010	17	6	16	0.9193	0.9665	0.879
2011	19	7	13	0.9917	1.0117	0.9982
2012	19	8	12	0.9327	0.9992	0.8051
2013	19	7	13	0.9145	1.0053	0.8366
2014	18	7	14	0.9113	0.9572	0.8767

As is shown in Fig. 3, there are nine sectors whose technical progress bias carbon resource conservation between C/K and C/L, including mining of other mineral (X_6), farm and sideline food processing industry (X_7), food manufacturing industry (X_8), beverage manufacturing (X_8),wood processing and wood, bamboo, cane, palm, grass products industry (X_{14}), stationery and sporting goods manufacturing industry(X_{18}), pharmaceutical manufacturing industry (X_{21}),electrical machinery and equipment manufacturing industry (X_{32}),Arts and crafts and other manufacturing (X_{35}).It can be thought that carbon resources have higher outflow impulse, which means it has higher "potential energy". And these industries themselves are higher technology industry.

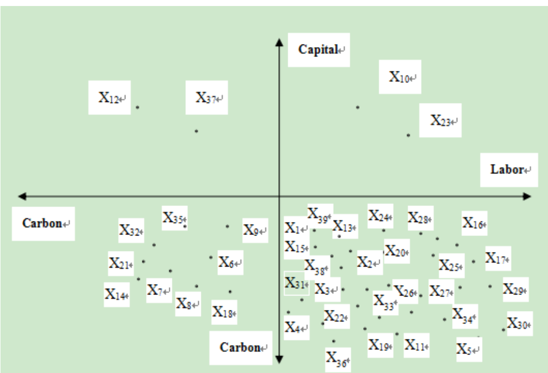

Fig. 3. The distribution of technological progress bias in China's industrial sector.

But, the technology progress of tobacco industries (X_{10}) and rubber products industry (X_{23}) bias capital and labor saving. which shows that the two industrial sectors do not have potential energy that carbon resource flows outward. It can be found that the two sectors are smaller sectors relatively special.

In addition, technology progress of the industry of textile and garment, shoes, cap manufacturing industry (X_{12}) and electric, heat power production and supply industry (X_{37}) bias capital and carbon resource saving. These two sectors has a certain "potential energy" than those sectors whose technology progress bias the labor.The technical progress of remaining 26 sectors bias carbon resources saving and labor saving between C/K and C/L. These sectors have a certain carbon resource flows "potential energy" compared with sectors which technology progress bias capital.

3) *Analysis on the technical progress of China's high emission industries*

At present, the carbon quota carried out in high energy consumption and high emission industries in China's 7 carbon trading pilot.In order to further explore the technical progress bias of China's industrial sector after the carbon quota being implement, this paper screened 7 industries with the largest carbon emissions in 2014, including: electricity, heat production (X_{37}) and supply industry, petroleum processing and coking and nuclear fuel processing (X_{19}), ferrous metal smelting and rolling processing industry (X_{26}), coal mining industry (X_1), non-metallic mineral products industry (X_{25}), chemical raw materials and chemical products manufacturing(X_{20}), non-ferrous metal smelting and rolling processing industry (X_{27}).

In order to study the technical progress factor bias in the 7 industry sectors, so as to define the "potential energy" of carbon resources among them, and explain the dynamic evolution, this paper divided 2001-2014 into three stages:

“10th Five-Year” period of 2001-2005, the "11th Five-Year" of 2006-2010, and in spite of 2011-2014 lack of 2015, generally able to represent the development of the "12th Five-Year" period. Through the calculation and settlement of technological progress bias in three stages, we can get the results showed in Table IV.

From the Table IV, the technical progress of the 7 industry sectors bias carbon resources saving between capital and carbon resources, raw material and carbon resources. But it bias labor saving between the carbon resources and labor. This result illustrates the two aspects of the problem, the first is that the demographic dividend of China's industrial sector is gradually disappearing; the second is the technological progress bias carbon resource conservation in China’s industrial sector, so China’s industrial system operation is in the process of gradual optimization.

TABLE IV: THE TENDENCY OF TECHNOLOGICAL PROGRESS IN VARIOUS STAGES OF CHINA'S HIGH ENERGY CONSUMPTION INDUSTRY

Industry number	the period of 10th Five-Year			the period of 11th Five-Year			the period of 12th Five-Year		
	C/K	C/L	C/M	C/K	C/L	C/M	C/K	C/L	C/M
X37	*C*	*L*	*C*	*C*	*L*	*C*	*C*	*L*	*C*
X19	*K*	*L*	*C*	*C*	*C*	*C*	*C*	*L*	*C*
X26	*K*	*L*	*C*	*C*	*L*	*C*	*C*	*L*	*C*
X1	*C*	*L*	*C*	*N*	*N*	*N*	*C*	*L*	*C*
X25	*K*	*L*	*C*	*C*	*L*	*C*	*C*	*L*	*C*
X20	*K*	*L*	*C*	*C*	*C*	*C*	*C*	*L*	*C*
X27	*K*	*L*	*C*	*C*	*C*	*C*	*C*	*L*	*C*

Although this chapter do not explore the technological progress bias in 7 high emission industries, we get another important conclusion that the technological progress in the whole China's industrial sector bias carbon resource conservation. China’s industrial system in the process of gradual optimization. The different potential energy coming from the technological progress bias, exist in industrial sectors. And this kind of "potential energy" of carbon resource flow, is the technological progress bias carbon resource conservation, which makes the industrial system in the state of continuous optimization of low carbon entropy reduction.

VI. CONCLUSION

As part of the National Natural Science Foundation of China, "CTP Spiral Driven Industrial System Low Carbon Evolution and Policy Guidance under Quota Embedding Mode", in order to further discuss the effects of carbon resource flow, technological progress and policy optimization (CTP) on industrial system entropy reduction, this paper clarifies the specific mechanism of CTP-driven industrial system's spiral low-carbon evolution, and describes the vertical interweaving rise and the horizontal mutual influence. As the same time, taking the technological progress as the starting point of the study, beginning with the industrial sector's technological progress bias, the paper discusses that technological progress bias will result in the carbon resources in industry sectors have "potential energy" flowing from one sector to another based on the actual data of China's industrial sector. Finally, this paper demonstrates the fact that the implement of carbon quota will spur carbon resources flowing among industry sectors, achieve the entropy reduction of industrial system and drive low carbon evolution of industry system.

Firstly, based on the statement of the technological progress factor bias and the induced mechanism of technological progress bias, this paper discusses that different technological progress bias in manufacturer or industry is an important factor caused them to decrease output, develop technology or purchase quota. What’s more, the "potential energy" analogy with physics study is put forward, we describe the tendency of carbon resource flow between sectors caused by technical progress bias with “potential energy”, which constitute the "half -hoop" of theory foundation of spiral low carbon evolution mechanism in industrial system.

Secondly, the paper compares the differences between TFP decomposition method and Translog Production Function in studying technological progress bias. DEA-malmquist index decomposition method in TFP decomposition is selected to study technological progress bias of China's industrial sectors. Then, according to the study of Weber & Domazlicky and Wang *et al*, this paper identifies the discrimination method of technical progress bias, laying the methodology foundation for the further study.

Finally, based on 2001_2014 China's 39 sector actual data, with the help of DEA-malmquist index decomposition of R software, we gain the following 4 conclusions : 1) There is technological progress bias in China's industrial system and it has gain effect on productivity; 2) The technological progress bias is sTable in China's industrial system; 3) The technology progress overall bias carbon resource saving; 4) By using cross coordinates, we sorted out that 9 industry departments’ technology progress bias carbon resource conservation, 2 industries departments completely not biased towards carbon resource conservation. So that carbon resource flow “potential energy” is demonstrated; 5) The whole industrial sectors’ technology progress bias carbon resource conservation, industrial system is working in the process of gradual optimization.

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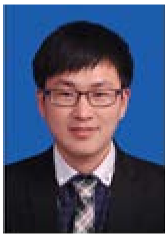

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