A study on regional total factor productivity in China from the perspective of low-carbon economy

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Abstract

With the rapid economic growth and the increasing environmental pollution, the development of low-carbon economy is the first choice to solve the current energy scarcity and harsh environment. It is an inevitable trend to consider low-carbon factors in the measurement of total factor productivity in all regions of our country. This paper uses the Malmquist productivity index method to analyze the change of TFP in different regions of China, and compare it with the traditional total factor productivity without considering the low carbon factor. It is found that a significant growth after China's total factor productivity into low-carbon factors, the growth of low-carbon total factor productivity is basically driven by changes in technological progress, the effect of efficiency changes on low-carbon total factor productivity is minimal.

Key words: *total factor productivity, malmquist index, direction-distance function, low- carbon economy*

1 Introduction

With the rapid economic growth, it is accompanied by huge consumption of energy and environmental degradation, as well as the low efficiency of production. Developing low-carbon economy is an important breakthrough to solve the problem. The new economic growth theory holds that "technological progress" is the core of economic growth, the "technological progress" here refers to how to improve the TFP.[1] The research methods of TFP have been innovating, there are four main ways of getting familiar with it: production function method, growth accounting method, data envelopment analysis method and stochastic frontier analysis method. The first two methods need to set the form and parameters of the function. DEA is a nonparametric method that does not require specific functions to be specified, it uses the ML to calculate the total factor growth rate by measuring the relative efficiency of input and output. Its main idea is the production function, the elements of inputs include labor, capital, GDP as an indicator of output. Many scholars have studied the efficiency of economic growth from the perspective of total factor productivity, such as Wang Xiaolu et al. (2009),[2] but they all ignore the negative impact of environmental pollution . In this paper, the energy input and CO_2 emissions are put into the production function to calculate the TFP of China, which is more in line with the characteristics of low carbon economy and green economy.

2 Research on total factor productivity based on low carbon economy

This paper will use ML to set two cases, compare and analyze the two cases of China's 30 provinces TFP (Tibet doesn't take into account with the lack of data) : One is not considering the energy input and carbon dioxide emissions, only considers the expected output, and calculates the TFP in the traditional sense (hereinafter referred to as ITFP); the other is to measure the TFP of low-carbon by introducing the direction distance function (DDF) in the perspective of low-carbon economy (hereinafter referred to as CTFP). Study the dynamic change process on this basis, further decompose TFP into technological progress index and technical efficiency index to study the causes of TFP change, and regional variation.

It is well known that the traditional ML is based on the Shephard distance function, which can only be used to minimize the input or output maximization in a certain direction of input or output, unable to effectively take into account the dual target of the economic growth and the emission reduction. The energy and capital stock and the labor force are invested as inputs, the regional GDP is treated as an output indicator, in the treatment of CO_2 emissions ,either take it as an input factor or convert it to a "good" output by multiplying (-1) or take the reciprocal of it. [3] Although this approach takes into account the impact of the expected output on production efficiency, it is clearly contrary to the actual production process. In order to incorporate environmental pollution emissions into the framework of analysis, this paper constructs a set of production possibilities that contain both good output (GDP) and bad output (CO_2) according to Fare et al. (2007) .[4] The CO_2 emissions were multiplied by (-1), and the CTFP was analyzed using the directional distance function.

We assume that the environmental technology faced by each decision making unit (DMU) is made up of M kinds of inputs $x=(x_1,x_2,\cdots,x_m)\in R_+^M$, N kinds of good outputs, $y=(y_1,\cdots,y_n)\in R_+^N$ and I kinds of bad outputs, $b=(b_1,\cdots b_i)\in R_+^I$ and the input and good output of environmental technology can be freely disposed of. In addition to satisfying the standard axiom, it also needs to satisfy two environmental axioms: First，the joint weak disposal, which means that the treatment of environmental pollution emissions needs cost, and the reduction of bad output will certainly indicate the transfer of resources from the production process of expected output; The second is zero combined axiom which means that the bad output is expected by the output of the by-product. Define the vector $g=(y^t,-b^t)$ as the direction vector of output expansion, which allows increase the output and reduce the bad output synchronously. Then, the directional distance function of $t+1$ period technology and t period input and output data can be defined as :

$$\vec{D}_0^{t+1}(x^t,y^t,b^t;g_y,g_b)=\sup\{\beta:(y^t+\beta g_y,b^t-\beta g_b)\in T^{t+1}(x^t)\} \quad (1)$$

Based on the directional output distance function, we can define the ML. It is proved that the ML is completely equal to ETFP in the case of constant returns to scale, and we use CTFP expression. Chung et al. (1997) defined the ML for the two-period direction distance function based on t and t + 1 periods as follows:

$$ML_t^{t+1}=\left\{\frac{1+\vec{D}_0^t(x^t,y^t,b^t;y^t,-b^t)}{1+\vec{D}_0^t(x^{t+1},y^{t+1},b^{t+1};y^{t+1},-b^{t+1})}\times\frac{1+\vec{D}_0^{t+1}(x^t,y^t,b^t;y^t,-b^t)}{1+\vec{D}_0^{t+1}(x^{t+1},y^{t+1},b^{t+1};y^{t+1},-b^{t+1})}\right\}^{\frac{1}{2}} \quad (2)$$

This index can decompose the TFP into two parts: efficiency change and technological progress:

$$ML_t^{t+1}=CTEH_t^{t+1}\times CTP_t^{t+1} \quad (3)$$

Where CTEH is the low carbon efficiency change index, which represents the degree which the decision-making unit moves to the forefront of the best production. CTP stands for the technological progress index, which represents the technological innovation of the decision-making unit. ML (CTFP), CTEH, CTP greater than 1 means productivity growth, efficiency improvement and technological progress; less than 1 means productivity degradation, efficiency deterioration and technical regression.

3 The selection of variables and data description

The data selected in this paper mainly come from the China Statistical Yearbook , China Energy Statistical Yearbook . The variables are described as follows:

GDP: The calculation method is based on the GDP of the year in 2000 as the base period, and then multiplied by the 2001 - 2014 provinces over the years for the base period constant price of the development index. Capital stock (K): using the physical capital stock as the capital input index. This paper use the perpetual inventory method to estimate the capital stock of China according to Zhang Jun et .[5] Labor input (L) is expressed as "the number of employees at the end of the year" in the statistical yearbook. Energy inputs (E): In this paper, the use of regional energy terminal consumption as energy input data. CO_2 emissions defined as follows： CO_2 emissions = carbon energy consumption × carbon conversion coefficient × CO_2 gasification coefficient. Among them, coal, crude oil and natural gas consumption converted into 10,000 tons of standard coal; CO_2 gasification coefficient is defined as the ratio of carbon to total mass before CO_2 is completely oxidized which is a standard amount of 3.67 (ie 44:12); the carbon conversion coefficient is 0.67 in line with national development and Reform Commission Energy Research Institute of the coefficient.[6]

4 The empirical results

In order to study the change of total factor productivity and environmental total factor productivity in China, this paper uses DEAP2.1 software to calculate it.

4.1 Total factor productivity change

Table 1 - Estimated results of the Malumquist index for 2000-2014

Time	ITFP	CTFP	ITEH	CTEH	ITP	CTP
2000-2001	0.988	1.026	1.025	1.005	0.964	1.021
2001-2002	0.977	0.940	1.016	1.004	0.962	0.936
2002-2003	0.978	0.978	1.006	0.996	0.972	0.982
2003-2004	0.984	0.986	1.008	1.002	0.976	0.984
2004-2005	0.971	0.980	0.994	0.996	0.977	0.984
2005-2006	0.977	0.975	0.991	0.985	0.986	0.990
2006-2007	0.975	0.977	0.988	0.985	0.987	0.992
2007-2008	0.969	0.974	0.992	0.990	0.977	0.984
2008-2009	0.964	0.978	0.990	0.992	0.974	0.986
2010-2011	0.970	0.969	0.997	0.986	0.973	0.983
2011-2012	0.968	0.974	0.992	0.987	0.976	0.987
2012-2013	0.968	0.974	0.991	0.992	0.977	0.982
2013-2014	0.958	0.976	0.986	0.993	0.972	0.983
Average	0.972	0.978	0.999	0.993	0.973	0.979

The results of Malumquist TFP, technical progress index and technical efficiency index considering and without considering low-carbon factor are shown in Table 1.

From Table 1, we can see that China's CTFP is greater than 1 during 2000-2001, and the rest of the period is less than 1, It can be seen that China's CTFP is only slightly increased from 2000 to 2001, and almost are driven by technological progress. After 2002, it showed a downward trend and the technical efficiency of the change is not significant, this is similar to the previous study of scholars. *Sun Chuanwang* (2010) argue that changes in TFP are mainly due to changes in technological progress.[7]Based on the above analysis can be found: the early 20th century, Low carbon technology progress rate has become the dominant force of CTFP growth; But in the following years, the change of low-carbon technological progress is not obvious, It shows that the technology is not very advanced in the process of economic development in China, and lags behind in foreign countries, also reflects China's high energy consumption, crude emissions, the production mode has not been completely improved.

4.2 Analysis of total factor productivity change and difference in each region

Table 2 shows the ML index with and without adding low-carbon factors in various regions of China. As can be seen , from 2000 to 2014, the average growth rate of TFP increased from -2.8% to -2.2% when adding energy variables and carbon emissions . It is indicating that the CTFP is higher than the TFP. Because the consideration of low-carbon factors can make the production process to improve the environmental pollution, the effective use of energy as a contribution to the production rate. The technical progress rate was reduced from -2.7% to -2.1%, and the technical efficiency dropped from -0.1% to -0.7%.At the regional level, the TFP in the three major regions has experienced a downward trend. The technical efficiency of the central and western regions shows an increasing trend, but in the eastern region is declining. It is indicating that in the absence of low-carbon factors, the use efficiency of technology in the eastern region is not high , however, due to the superior geographical position, absorbing advanced technology has great advantages, so that the cutting edge of technology in a leading position. In the central and western regions, the opening time lags behind the east part, the upgrading of production technology is mainly rely on imitation and transformation, it is led to the central and western regions can make full use of the eastern transfer technology. The technical efficiency and technological progress index of the eastern region are in a leading position, the efficiency of low carbon technology in the central and western regions is lower than that of traditional technology efficiency. From different provinces, the highest TFP is Beijing , and the lowest one is Jiangxi ; the highest CTFP is Shanghai, and the lowest is Hainan.

Table 2 - Malumquist index of China from 2000 to 2014

Area	ITFP	CTFP	ITEH	CTEH	ITP	CTP
Beijing	1.100	1.021	1.072	0.974	1.026	1.048
Tianjin	1.008	1.008	1.002	1.002	1.006	1.006
Hebei	0.976	0.978	1.000	1.000	0.976	0.978
Liaoning	0.977	0.978	0.971	0.972	1.006	1.006
Shanghai	1.041	1.049	1.000	1.000	1.041	1.049
Jiangsu	0.993	1.010	0.992	0.995	1.001	1.015
Zhejiang	1.001	0.999	0.996	0.995	1.005	1.004
Fujian	0.990	0.987	0.998	1.000	0.992	0.987
Shandong	0.982	0.990	0.990	0.996	0.992	0.994
Guangdong	1.003	0.998	1.001	1.000	1.002	0.998
Guangxi	0.986	0.985	1.006	0.981	0.980	1.004
Hainan	1.000	0.919	1.020	0.981	0.980	0.937
Shanxi	0.943	0.945	0.990	0.992	0.953	0.953
Neimenggu	0.961	0.970	0.980	0.985	0.981	0.985
Jilin	0.974	0.974	0.981	0.980	0.993	0.994
Heilongjiang	0.995	1.004	1.010	1.018	0.985	0.986
Anhui	0.939	0.959	1.002	0.992	0.937	0.967
Jiangxi	0.905	0.962	0.976	0.982	0.927	0.980
Henan	0.920	0.934	1.000	0.990	0.920	0.943
Hubei	0.941	0.921	0.990	0.990	0.950	0.930
Hunan	0.951	0.954	1.014	0.992	0.938	0.962
Chongqing	0.982	0.974	1.004	0.998	0.978	0.976
Sichuan	0.944	0.950	1.006	0.987	0.938	0.963
Guizhou	0.947	0.947	1.011	1.011	0.937	0.937
Yunnan	0.959	0.948	1.013	0.991	0.947	0.957
Shanxi	0.950	0.931	1.014	0.991	0.937	0.939
Gansu	0.949	0.958	0.996	0.992	0.953	0.966
Qinghai	0.986	0.988	0.999	1.000	0.987	0.988
Ningxia	0.975	0.971	0.986	0.982	0.989	0.989
Xinjiang	1.002	1.000	0.994	0.993	1.008	1.007
east	0.993	0.997	0.993	0.996	1.001	1.002
central	0.955	0.958	1.001	0.991	0.954	0.967
west	0.965	0.963	1.001	0.994	0.964	0.969
Average	0.972	0.978	0.999	0.993	0.973	0.979

By comparing and analyzing the change of TFP and CTFP, it can be found that the CTFP of Beijing, Hainan, Guangdong, Hubei and other provinces is lower than TFP ,which shows that the economic development of these provinces is at the expense of energy consumption and environmental pollution; On the contrary, the growth rate of CTFP increased significantly in Jiangxi, Anhui, Shanghai and Jiangsu, it is indicating that these areas pay great attention to the protection of environment and the effective utilization of energy while developing economy.

5 Conclusions and policy recommendations

In this paper, we use the DDF and the MLindex to measure the TFP and CTFP, then make a comparative analysis. The existing findings are as follows:

1.Economic growth must take into account the deterioration of the environment. After considering the low carbon factor, the TFP has been improved, the change of TFP is mainly driven by technological progress and changes in technical efficiency have little impact on this. In recent years, low-carbon technology progress rate is declining slowly, it is indicating that we are not good at dealing with environmental pollution and the effective use of energy , the technology is not advanced enough.

2.From the regional level, the growth rate of CTFP shows an increasing trend , the CTFP has increased obviously in the eastern provinces such as Shanghai and Jiangsu which is indicating that these provinces pay attention to environmental protection and the use of energy at the same time as economic development.

Considering the above analysis, this paper presents several policy recommendations as follows. First of all, the development of low carbon economy must fully coordinate the relationship between energy utilization, environmental protection and economic growth. It is necessary to guide all regions to develop new industrialization road with high technology, good economic benefits, low resource consumption and less environmental pollution. secondly, we need to learn from foreign advanced technology, improve the efficiency of resource utilization, improve allocative efficiency, take the road of sustainable development. Finally, the development of China's central and western regions is not balanced, We have to invest more support and technical guidance in the western regions.

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