An analysis on the growth and effect factors of TFP under the energy and environment regulation: data from China

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Abstract

The paper analyses the growth and effect factors of TFP (Total factor productivity) under the energy and environment regulation with the data of China from 2002 to 2012. The results show that: in the past 10 years, without considering the energy and environmental regulation, the average annual growth rate of TFP is 3.2%, but it is 2.7% when considering them. The technological progress is the major contributor to TFP under the energy and environment regulation. From the comparison of various provinces, the growth difference of TFP was great. The TFP value in eastern coastal region is higher than that in the central and western regions. From the time trend, the average growth rate of TFP is in the lower. After the financial crisis of 2008, the TFP starts to decline and the average annual growth rate is -0.3%. The three variables of the FDI， environmental regulation intensity and industrial structure have a negative impact on TFP growth, but the two variables of R&D investment and energy consumption structure have a positive impact on it.

Keywords: environmental pollution, energy regulation, TFP, effect factors

1 Introduction

Since more than 30 years' reform and opening up policy, the annual growth rate of economic reaches 10% in China. But by the rapid economic growth, there are a number of problems, such as low resource utilization efficiency, environmental degradation and loss of environmental health which make the sustainable development face severe challenges. The energy consumption had increased by more than four times in 2000-2008 than that in the 1990s. At the same time, the polluted environment and changing climate by a lot of energy consumption which also bring a huge ecological and environment pressure to the social development. In 2010, the world's environmental performance index (EPI) ranking, China had the score of 49 which was 121st in 163 countries and regions, the international community gives a growing awareness of environmental problems in China [1].

According to the theory of modern economic growth, economic growth comes from two aspects: one is the inputs such as capital and labour, the second is from the improvement of TFP (Total factor productivity). Lack of per capita resources, environment pressure, and the growth of output relies on the input which is not sustainable. Therefore, the future economic growth must rely on the improvement of TFP in China. But the traditional measure of TFP does not consider environmental factors, also does not take the energy factors into account. With the resource and environmental problems in the process of economic development, more and more scholars think the resources and environment are not only the endogenous variables, but also the rigid constraints. Therefore, assessing economic performance by the TFP does not only consider the traditional factors of capital and labour, but also consider the resources and environmental factors which have a huge impact on economic growth.

Although Zhang [2], and other scholars measure the TFP in each province of China under energy and environment regulation, but the study does not consider the energy regulation, and it does not analyse the influence factors of TFP. On this basis, this paper researches the TFP in China on energy and environmental constraints, and analyses its reasons. Meanwhile, this study plays an important role for the Chinese government to guide transformation of economic structure and adjust the green GDP accounting target. This paper gives an empirical analysis by the data of China.

2 Literature review

At present, there are a large number of literatures on the research of total factor productivity. These literatures can be divided into two categories: the first kind of literatures does not consider environment pollution and energy input when measuring productivity. Most of these studies analyse the TFP by the Solow residual method, Malmquist index method and the stochastic frontier production function method. The capital and labour are the inputs, and the GDP is the output. The research results show that the TFP has been increasing in China, and it has more and more influence on the economy [3-6]. The second kind of literatures which put the environmental factor into the TFP framework. The related results show that the different provinces of China are as the research object, and it

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analyses the TFP growth under the constraints of SO_2 and CO_2 emissions. The results show that when considering environmental factors, the growth rate of TFP was only 1/3 of the conventional measurement value [7]. It estimates the TFP in manufacturing industry by the Directional Distance Function and Malmquist-Luenberger productivity indicator Function, and the results shows that the TFP presents a growth trend when considering the environmental factors. The factors of capital deepening, industry scale, spending of R&D and environmental pollution have different degree of influence on the TFP in light industry and heavy industry [8]. It analyses the agricultural TFP when considering the pollution in agricultural as a "bad" output, the results show that the agricultural TFP growth obviously under the environment constraint in China, and the growth is mainly driven by the agricultural technology progress. The agricultural TFP in each region appears different degree of deterioration. From the point of regional differences, the TFP presents the decreasing in east, west and the centre under environment regulation [9]. It estimates the TFP in energy-intensive industry by the directional distance function and non-parametric DEA method, and the results shows that the growth of TFP is mainly driven by technological progress. The status quo of China shows that the TFP in current energy intensive industry has greater room for improvement. The growth of TFP in each province presents different degree of convergence. Market-oriented reform, FDI inflows and the decline in energy intensity are all conducive to the growth of TFP [10].

3 Research method

In order to put the environmental factors into the productivity analysis framework, it need to construct a production possibility set which includes good and bad output, namely the environmental technology. Suppose each region using N kind of input, $X=(X_1,...,X_N)\in R_N^+$, and produce M kind of good output, $Y=(Y_1,...,Y_N)\in R_m^+$. At the same time, it also produces I kind of bad output, $b=(b_1,...,b_I)\in R_I^+$, so the production possibility set of environmental technology is:

$$p(x)=\left[(y,b):(y,b\in p(x),x\in R_+^N)\right]. \tag{1}$$

Due to the purpose of this study is that keeping the bad output to decrease and the good output to grow. Therefore, the bad output in technology has weak disposability. By the directional distance function [11], the equation is expressed as:

$$\overrightarrow{D_0}(x,y,b;g)=\sup\left\{\beta:(y,b)+\beta_g\in p(x)\right\}, \tag{2}$$

where $g=(y,-b)$ is the Direction Vector and β is the directional distance function. It measures the increasing value of good output while maintaining the bad output reduces under the condition of certain inputs. The directional distance function can be represented by the following mathematical equation:

$$\begin{aligned}
&\overrightarrow{D_0^t}(x_k^t,y_k^t,b_k^t;y_k^t,-b_k^t)=\max\beta,\\
&s.t.\sum_{k=1}^{k}\lambda_k^t y_{km}^t\geq(1+\beta)y_{k'm}^t, m=1,...,M,\\
&\sum_{k=1}^{k}\lambda_k^t u_{ki}^t=(1-\beta)u_{k'i}^t, i=1,...,I,\\
&\sum_{k=1}^{k}\lambda_k^t x_{kn}^t\leq x_{k'n}^t, n=1,...,N,\\
&\lambda_k^t\geq 0, k=1,...,K.
\end{aligned} \tag{3}$$

To solve the evaluated problem of TFP when considering the case of bad output, Chung et al. [12] put forward the Malmquist-Luenberger productivity indicator by the environmental DEA technology and direction distance function [12]. The ML productivity indicator from t to t + 1 period is as following:

$$ML_t^{t+1}=\left[\frac{1+\overrightarrow{D_0^t}(x^t,y^t,b^t;g^t)}{1+\overrightarrow{D_0^t}(x^{t+1},y^{t+1},b^{t+1};g^{t+1})}\times\frac{1+\overrightarrow{D_0^{t+1}}(x^t,y^t,b^t;g^t)}{1+\overrightarrow{D_0^{t+1}}(x^{t+1},y^{t+1},b^{t+1};g^{t+1})}\right]^{1/2}. \tag{4}$$

The ML productivity indicator can be decomposed into the technical changing efficiency (MLEC) and technological progress index（MLTC):

$$ML_t^{t+1}=MLEC_t^{t+1}\times MLTC_t^{t+1}, \tag{5}$$

$$MLEC_t^{t+1}=\frac{1+\overrightarrow{D_0^t}(x^t,y^t,b^t;g^t)}{1+\overrightarrow{D_0^{t+1}}(x^{t+1},y^{t+1},b^{t+1};g^{t+1})}, \tag{6}$$

$$MLTC_t^{t+1}=\sqrt{\frac{1+\overrightarrow{D_0^{t+1}}(x^t,y^t,b^t;g^t)}{1+\overrightarrow{D_0^t}(x^t,y^t,b^t;g^t)}\times\frac{1+\overrightarrow{D_0^{t+1}}(x^{t+1},y^{t+1},b^{t+1};g^{t+1})}{1+\overrightarrow{D_0^t}(x^{t+1},y^{t+1},b^{t+1};g^{t+1})}}. \tag{7}$$

The ML indicator measures the change of productivity from t to $t+1$. If ML=1, it shows the productivity declines. If ML>1, it shows the productivity improve. If ML<1, it shows the productivity remains the same. If $MLEC$>1, it shows the decision-making unit to be near the production frontier and the efficiency improves. If $MLEC$<1, it shows the efficiency declines. If $MLEC$=1, it shows the efficiency remains the same. If $MLTC$>1, it shows the technological progress of decision-making unit. If $MLTC$<1, it shows the technological retrogression of decision-making unit. If $MLTC$=1, it shows the technical level is constant.

4 Empirical analysis

The input indicators include the capital deposit, number of employed persons and total energy consumption. It calculates the capital stock by perpetual inventory method, and the formula is $K_{it} = K_{it-1}(1-\lambda) + I_{it} / P_{it}$. In the formula, λ is the depreciation rate, the value is 10%, I is the newly increased fixed assets, P is the price indices for investment in fixed assets in each province, and this index reduced for the year of 2000.

The paper references the method of Dai Yongan (2010) [13], the initial capital stock is equal to the total investment in fixed assets divided by 10% in 2002. The labours are the number of staff for each region. The energy consumption refers to the various energy consumption in various regions, including oil, coal, natural gas, electricity, etc. For the unified unit, this paper converts the consumption of various energy into 10000 tons of standard coal (SCE).

The output indicators include good output and bad output. The good output refers to the GDP, and the GDP data converts into the constant in 2000. The bad output is represented by industrial s SO_2 in each region.

The paper bases on the data of 30 provinces in China from the year 2002 to 2012. Because of the lacking of data in Tibet, it doesn't analyse.

4.1 THE TFP UNDER THE ENERGY AND ENVIRONMENT REGULATION

The paper calculates the TFP under energy and environment regulation by the output data of 30 provinces in China. Meanwhile, the TFP is divided into the MLTC and MLEC. The data in Table 1 is the geometric mean for 2002 to 2012 which reflects the regional differences and average growth. The Figure 1 is the geometric average value in each region, which reflects the changing trend of ML, MLTC and MLEC over time.

From Table 1 and Figure 1 is is seen:

1) Overall, there is a rapid growth of TFP under energy and environment regulation in China. In the past 10 years, the average growth has reached 2.7%, among them, the average annual growth of technological progress is 4.2%, while the technical efficiency has reduced by 1.5% per year on average. The technological progress is the main contributor to TFP.

2) The growth of TFP has great difference among regions in China. The fastest growth is Liaoning, with an average annual growth rate of 15.1%, and 12.4% above the average. In addition, the growing bigger include the eastern provinces of Jiangsu, Guangdong, Beijing, Shandong, Shanghai, Tianjin, etc. The low growth rate are the central and western provinces of Xinjiang, Henan, Ningxia, overall, Heilongjiang, etc. The average annual growth rate is less than 1%. It can be seen that the TFP value in eastern region is far higher than that in the centre and west from 2002 to 2012.

3) The TFP continuously grows in most provinces, but the TFP appears backwards a few provinces. The TFP have reduced include the midwest provinces of Shanxi (-4.6%), Guangxi (-3.7%), Chongqing (-2.0%), Qinghai (-0.9%), Hunan (-0.4%), Neimenggu (-0.2%).

4) From the time trend, growth rate of TFP gradually reduces in China. The average annual growth rate in 2003 was 8.4%, 6.6% in 2004, 4.1% in 2007, and it appeared a significant reduction in 2008, only 0.9%. It fell by 3.2% comparing with 2007. The growth rate in 2009 was -0.1%, while it increased slightly by 0.1% in 2010. It was a negative growth in 2011 and 2012, the growth rate of 1.5% and 0.7%. This paper argues that it is mainly due to the financial crisis in 2008, which made the exports and economic downturn in China.

TABLE 1 The TFP and its decomposition under energy and environment regulation (2002-2012)

Region	ML	MLTC	MLEC
Beijing	1.083	1.083	1
Tianjin	1.064	1.078	0.987
Hebei	1.024	1.063	0.963
Shanxi	0.954	1.016	0.94
Neimenggu	0.998	1.027	0.972
Liaoning	1.151	1.155	0.997
Jilin	1.024	1.042	0.983
Heilongjiang	1.008	1.019	0.99
Shanghai	1.066	1.066	1
Jiangsu	1.101	1.101	1
Zhejiang	1.044	1.04	1.004
Anhui	1.045	1.058	0.988
Fujian	1.013	1.013	1
Jiangxi	1.005	0.976	1.03
Shandong	1.072	1.072	1
Henan	1.003	1.046	0.958
Hubei	1.023	1.032	0.99
Hunan	0.996	1.021	0.975
Guangdong	1.091	1.091	1
Guangxi	0.963	1.005	0.958
Hainan	1.014	1.03	0.985
Chongqing	0.98	1.034	0.948
Sichuan	1.025	1.046	0.98
Guizhou	1.022	1.021	1.002
Yunnan	1.019	1.048	0.972
Shanxian	1.029	1.034	0.995
Gansu	1.012	1.015	0.998
Qinghai	0.991	1.019	0.972
Ningxia	1.004	1.007	0.997
Xinjiang	1.002	1.021	0.981
Average	1.027	1.042	0.985

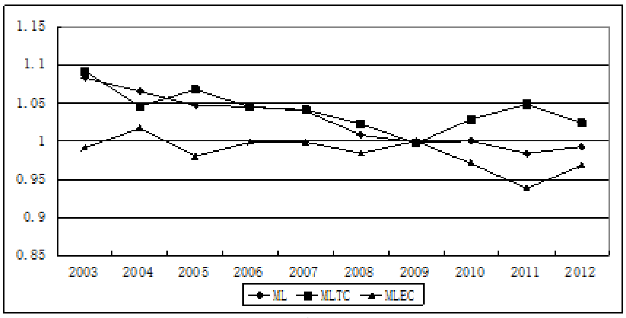

FIGURE 1 The changing trend of ML, MLTC and MLEC over time

4.2 THE COMPARISON OF TFP IN TWO CIRCUMSTANCES

If it does not consider the energy constraints and bad output, there may be a large error for the calculated results of TFP. Therefore, this paper gives a comparison of the results in two circumstances. Figure 2 shows the comparison of productivity index, the technical progress and technical efficiency in both cases for 30 provinces:

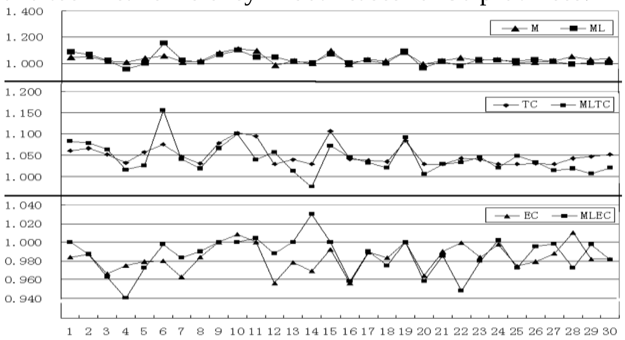

FIGURE 2 The comparison of TFP in two circumstances

As can be seen from the Figure 2, when considering the energy constraints, and bad output, the annual growth rate of TFP declines in most provinces. The growth rate of TFP falls from 3.2% to 2.7%, which shows that the economic growth in most regions of China still basing on the guidance of GDP growth. It consumes a lot of energy and emissions of pollutants. But there are also some provinces such as Beijing, Liaoning, Anhui and other regions, after considering energy constraints and bad output, the growth rate of TFP has been increasing. These provinces appear the *potter win-win* situation. When considering energy and environmental factors, the average annual growth rate of technical progress is from 5.0% to 4.2%, reducing by 8% a year. Among them, the technological progress index falls in 19 provinces which show the measure result of technological progress is overvalued. The average annual growth rate of technical efficiency in each region decreases from -1.7% to -1.5% which shows the energy and environment have less effect on the technical efficiency. Only a few provinces of Shanxi, Anhui, overall and Chongqing appear a larger fluctuation.

5 The analysis of influence factors

What factors influence on TFP? According to the research achievements of other scholars, this paper gives an empirical analysis selecting the following indicators for influencing the growth of TFP:

1) The foreign direct investment. In developing countries, the inflow of FDI can bring the advanced production and management technology which will promote the growth of efficiency.

2) The environmental regulation intensity. After implementation of environmental regulation, the enterprise needs to increase the investment related to environmental protection which will increase the cost of enterprise. But if the enterprise does the innovation activities of technology, and use the new technology and new equipment which will reduce pollution. The intensity index of environmental regulation is expressed by the industrial SO_2 emissions compliance rate.

3) The R&D investment. The investment funds of science and technology can promote the rapid economic growth in a country. The R&D index can be represented by the proportion of expenditure for science and technology in government expenditure.

4) The energy consumption structure. The bad production by different energy is also different. The energy consumption structure can be represented by the proportion of coal consumption in total consumption of energy.

5) The industrial structure. There is a great difference between input and output in different industries which will affect green TFP in a region. The industrial structure index is represented by the ratio of added value in the second industry to GDP.

The model of influencing on TFP factors is as follows:

$$ML_{it} = \alpha + \beta_1 fdi_{it} + \beta_2 eri_{it} + \beta_3 rd_{it} + \beta_4 ecs_{it} + \beta_5 str_{it} + \varepsilon_{it}, \quad (8)$$

where ML is the green TFP. FDI is the foreign direct investment. The *eri* is the environmental regulation intensity. The *rd* is the R&D investment. The *ecs* is the energy consumption structure. The *str* is the industrial structure.

Due to unable to get data of some year, the paper gives an analysis by the data from 2005 to 2010. The regression analysis results are shown in Table 2:

TABLE 2 The regression analysis results for panel data

Variable	coefficient	t-statistic
fdi	-0.002	-0.03
Eri`	-0.146	-5.75
rd	0.011	1.52
ecs	0.137	4.41
str	-0.051	-0.54
adr^2=0.612	F=9.303	D.W. stat=1.44

1) The negative influence of FDI on the green TFP. The conclusion is the same as Li ling's [14]. Meanwhile, the conclusion verifies the "pollution haven hypothesis" which means the degree of environmental regulation of developed countries is higher than that in the developing countries. Therefore, a large amount of FDI flows to the developing countries. The FDI can promote the economic growth in developing countries, at the same time, it also brings a lot of pollution.

2) The negative influence of environmental regulation intensity on the TFP and it is through the test of significance. The conclusion shows that the implement of environmental protection measures in Chinese governments which increases the cost of enterprise and hinders the growth of green TFP. The conclusion also shows that the environment and economy without achieving common development in China, and the "potter win-win "situation is only in a few provinces.

3) The positive effect of the R&D investment on TFP, and it is through the test of significance at the 15% level. The R&D can improve the level of technology, improve the energy efficiency in regional economic growth, and reduce the pollution emissions.

4) The positive effect of the energy consumption structure on TFP. It does not agree with the expectations, and the possible reasons lie in the choice of inappropriate metrics.

5) The positive effect of the industrial structure on TFP, but it is not through the test of significance. The result shows that the high energy consumption and high pollution in industrial development is bad for TFP growth. The higher proportion of GDP, the slower of the green TFP.

6 Conclusion

1) If it doesn't consider the environmental regulation, the traditional method can lead to a great deviation for the TFP measurement. So the paper puts the environmental factor into the TFP analysis framework, and analyses the growth of TFP and influence factors with the data of 30 provinces in China. In the past 10 years, the average growth has reached 2.7%, and the average annual growth of technological progress is 4.2%, while the technical efficiency has reduced by 1.5% per year on average. The technological progress is the main contributor to TFP.

2) The growth of TFP has a great difference among regions in China. The TFP value in east is much higher than that in the midwest. The TFP in most provinces has been increasing, but the 6 western provinces of Shanxi, Guangxi, Chongqing, Qinghai, Hunan, and Neimenggu are backwards.

3) The growth rate TFP is in the lower in China. After the 2008 financial crisis, The TFP starts to decline, and the average annual growth rate is -0.3%.

4) When considering the energy regulation and bad output, the annual growth rate of TFP declines in most provinces. The growth rate of TFP falls from 3.2% to 2.7%, which shows that it invests a large amount of energy and emissions of pollutants for the economic growth in most provinces of China.

5) The three variables of FDI, environmental regulation intensity and industrial structure have a negative effect on green TFP, but the two variables of R&D investment and energy consumption structure have a positive impact.

At present, it is in a stage of rapid development in China. But for a long time, the disadvantages of economic growth path for "high investment, high pollution, high output" is more and more obvious. The living environment for Chinese residents deteriorates. According to the research conclusion, the following suggestions are put forward: First, in order to promote the growth of green TFP, the Chinese government must change the old development model. At the same time of relying on technological progress, it should strengthen the application of existing technology and improve the technical efficiency. Second, the government makes policy for transferring and diffusing the advanced environmental technology between different provinces which can effectively promote the environmental protection technology level in west. Third, it will optimize the industrial structure, promote the development of the third industry and reduce the proportion of secondary industry. Fourth, the local government should attach great importance to the serious pollution of FDI. Fifth, it will continue to implement the environmental regulation measures, play the advantages of market competition, integrate of the resources and factors of polluting industries, shut down the enterprises of backward technology, high energy consumption and high pollution and encourage the development of large enterprises of high level technology, less pollution and good benefit.

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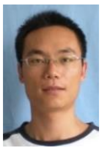

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