Advances in Social Science, Education and Humanities Research, volume 310

3rd International Conference on Culture, Education and Economic Development of Modern Society (ICCESE 2019)

Analysis of Urban Scale and Green TFP Growth*

Xiaoxue Guo

School of Statistics and Mathematics
Zhongnan University of Economics and Law
Wuhan, China

***Abstract*—With the further acceleration of urbanization process in China, the number of big cities and population are expanding rapidly and the development of small and medium-sized cities is slow. As a result, a phenomenon of polarization appears and each city also presents different characteristics of economic development. This paper focuses on the analysis of green TFP growth under different urban scales. Firstly, this paper analyzes the relationship between urban scale and green TFP, and calculates and decomposes the green TFP growth of 275 cities in China based on CRS-ML exponential model, and then respectively carries out analysis and comparative analysis of the green TFP growth of four different types of cities. Finally, the conclusion is that the driving force of urban green TFP growth mainly stems from technological progress, and efficiency has become the bottleneck restricting its growth; there are significant differences in TFP growth, efficiency and technology between cities of different sizes. Over time, it shows the characteristics of repeated fluctuations, and the reasons are analyzed. Finally, this paper puts forward corresponding policy recommendations.**

Keywords—urban green TFP; urban scale; technological progress; efficiency

I. INTRODUCTION

Since the reform and opening up, China has seen rapid growth in economic aggregate. But with the excessive consumption of conventional energy and increasingly prominent environmental pollution, single GDP growth is difficult to reflect a region's sustainable development ability. The Nineteenth National Congress of the Communist Party of China will take the promotion of total factor productivity as an important means to promote the quality, efficiency and dynamic revolutions of economic development, and point out the direction for promoting the high-quality development of China's economy. Most of the existing researches on TFP are based on national or provincial macro-level, and most of them ignore the "undesirable" outputs such as resource input and environmental pollution, so the conclusions are not accurate enough, nor can they reflect the goal of high-quality development. In addition, as a constituent part of regional economy, cities are the cells of macroeconomic operation. Under the background of the further deepening of urbanization in China, the development scale of different cities in China shows great differences as evidenced by cities of large scale gather more capital and high-quality labor resources, which lays the foundation for further economic growth. Compared with large scale cities, small and medium-sized cities are slightly disadvantaged. Therefore, the conduct of the analysis of the green TFP growth in cities of different scales can not only reflect the economic development characteristics of different types of cities, but also clarify the heterogeneity of urban development in different scales, so as to provide some reference for making economic decisions according to local conditions.

*Project: Innovation Subject of Graduate Students in Zhongnan University of Economics and Law, "Research on cultivation mechanism of dominant export industries in China — taking electronic information industry as an example"

II. THE RELATIONSHIP BETWEEN URBAN SCALE AND GREEN TFP GROWTH

Influenced by factors such as history, location and factor endowment, the scale of different cities varies greatly and shows different economic characteristics. Therefore, this paper firstly draws scatter plots to observe whether there is a certain relationship between urban size and green TFP growth.

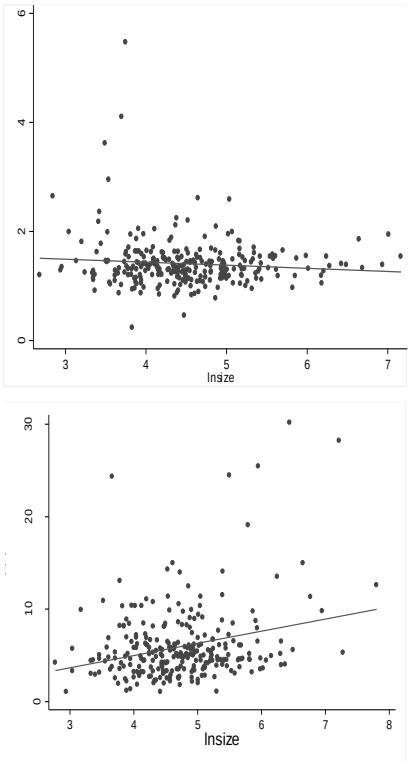

Fig. 1. Scatter plot of relationship between urban scale and green TFP growth.

"Fig. 1" is the scatter plot of the relationship between urban scale and green TFP growth in 2005 and 2016. From the plot, it can be seen that there is an obvious linear relationship between urban scale and green TFP growth. There is a negative correlation between them in 2005 and a positive correlation in 2016, which shows that with the expansion of urban scale, the growth rate of green TFP is gradually accelerating. In order to make a more detailed analysis of the development characteristics of cities of different sizes, this paper groups the total sample according to the 2014 standards of the State Council. At the same time, this paper divides Chinese cities into megacities, big cities, medium-sized cities and small cities according to the population of each city at the end of 2016.

III. RESEARCH AND DESIGN

A. Research Methods

Total Factor Productivity (TFP) refers to the ratio of total output to total input of factor number in an economic system, which reflects a comprehensive ability of the improvement of technological progress and management mode and others. There are two kinds of calculating methods: parametric method and non-parametric method. The parametric method is to set the production function on the basis of economic theory. The factor input deducted from the growth rate of output is classified as technological progress through metering method, that is, TFP growth. The classical parameter methods include "Solow Remaining Value" Method (R. Solow, 1957) and others. Non-parametric methods that are mainly based on DEA data envelopment method (Chames et. al., 1978) can deal with multi-objective decision-making problems, and its basic principle is to determine the production frontier according to the DEA method and get the distance function, and then use the distance function to construct the TFP index. All kinds of DEA methods can be used in any combination.

With the continuous improvement of DEA technology, the problem of resource consumption and environmental pollution are obtaining more and more attention. Total Factor Productivity (TFP) that incorporates resources and environment can more objectively measure the quality and efficiency of economic development of a region. Chung (1997) pointed out that the traditional productivity measurement idea of neglecting undesirable output would lead to biased productivity growth. Malmquist-Luenberger index (abbreviation as ML index) constructs the production possibility frontier of an economic entity with DEA technology, calculates the distance between each production decision-making unit and the production possibility frontier of an economic entity with "directional distance function", and finally calculates the ML index during this period based on "directional distance function" of two periods. At the same time, compared with ordinary DEA method, ML index includes not only "desirable output" but also "undesirable output". Therefore, this paper uses ML index of CRS multiplier with fixed period as the reference set as total factor productivity growth index that can be decomposed into efficiency change (EC) and technology change (TC):

$$M_f(x^{t+1},y^{t+1},x^t,y^t)=\frac{E^f(x^{t+1},y^{t+1})}{E^f(x^t,y^t)}=\frac{E^{t+1}(x^{t+1},y^{t+1})}{E^t(x^t,y^t)}\left(\frac{E^f(x^{t+1},y^{t+1})}{E^{t+1}(x^{t+1},y^{t+1})}\frac{E^t(x^t,y^t)}{E^f(x^t,y^t)}\right)$$
$$=EC\times TC_f$$

If the value of ML is greater than 1, it indicates that the TFP is in the increase during the period from t to t+1, and vice versa. Similarly, EC and TC indicate that the marginal output is equal to the degree of efficiency improvement and technological innovation in the average output state. Since reference of each period is a fixed frontier, it has transmissibility and can be multiplied, which is conducive to the conduct of the evolution analysis of urban green TFP.

B. Sample Selection, Data Source and Processing

The data in this paper stem from *China City Statistical Yearbook*, *Environmental Statistical Yearbook*, ESP database and the website of the National Bureau of Statistics. Due to the change of administrative region, the statistical caliber of Bijie and Tongren cities in Guizhou Province, Chaohu City in Anhui Province and Sansha City in Hainan Province are in disunity. In addition, because there are many data missing in Lhasa and Haikou and others, finally, this paper takes 275 urban data from 2003 to 2016 as samples. A few missing data are filled by interpolation method and regression filling method. According to the grouping basis in the previous paper, this paper eventually divides 275 cities into four groups, namely, 33 megacities, 117 big cities, 86 medium-sized cities and 39 small cities.

C. Index Selection Explanation

Based on the principles of comprehensiveness, effectiveness and rationality of index selection, and the goal of realizing the quality of economic development to the maximum extent, this paper finally selects the following input and output indices, as shown in "Table I".

In terms of input, as for capital input, the "total investment in fixed assets" is selected as capital input, but such index represents the concept of "flow" rather than "stock" that cannot be directly used to calculate. And because of price factors, it needs to be deflated according to GDP deflator index of corresponding years, and then calculates the capital stock of each city in the inspection period by the method of perpetual inventory. Specific calculation methods are as follows: Firstly, it needs to calculate the capital stock of all cities in 2003 as the base period on the basis of the reference of CH (1995), and the formula is $K_{it}=I_{it}+(1-\delta)K_{it-1}$, among which K_{i0} is the capital stock of the base period, g is the economic growth rate of that year and δ is the depreciation rate. And then on the basis of Zhang Jun's (2004) and other's practices, it needs to calculate the capital stock of each city. Specifically, the formula is $K_{it}=I_{it}+(1-\delta)K_{it-1}$, among which K_{it} is the capital stock of the city of i in the year of t, I_{it} is the fixed assets investment volume of the city of i in the year of t and δ is the depreciation rate. The choice of depreciation rate is generally considered to be between 5% and 10% (Li Cheng et al., 2014). Shan Haojie (2008) sorts out the depreciation rate of

the 1950s to the 1990s and believes that it does not exceed 7% after the 1990s. Finally, the depreciation rate is chosen as 6% according to the research of Hall (1999). Labor input is obtained by summing up "the number of employed persons per unit" and "the number of employed persons in private units". The resource input chooses total amount of water used and the total amount of electricity used.

In terms of output, the "gross domestic product" of each city is taken as the desirable output. Because of the short of GDP deflation index at the city level, the each province adjusts their GDP deflation index to constant price according to the corresponding year. Undesirable output selects the common pollutants in cities such as "sulphur dioxide", "waste water" and "smoke dust".

TABLE I. DESCRIPTIVE STATISTICS OF INPUT-OUTPUT VARIABLES

Variable	Unit	Maximum Value	Minimum Value	Mean Value	Standard Deviation	Observation Value
Capital Stock	10,000 yuan	629616742.1	174715.2	24598176.3	51555998.0	3850
Labor Force	10,000 people	107086.0	1.9	83.3	1728.8	3850
Total Water Supply	10,000 t	349481.0	360.0	15791.4	30854.1	3850
Total Power Consumption	10,000 kWh	14860200.0	1798.0	749121.7	1300640.0	3850
Gross Domestic Product	10,000 yuan	413103310.3	125071.6	12480914.9	29487150.0	3850
Waste Water	10,000 t	91260.0	88.0	7559.7	9671.0	3850
Sulfur Dioxide	10,000 t	71.2	6.4E-03	5.9	6.0	3850
Smoke Dust	10,000 t	516.9	4.7E-03	3.4	12.2	3850

IV. ANALYSIS OF GREEN TFP GROWTH IN CITIES OF DIFFERENT SCALES

According to the ML index model of CRS multiplier, this paper obtains the result of green TFP growth of 275 cities and analyzes such data in groups. In order to make the analysis of four groups of cities of different sizes more intuitive, this paper carries out the multiplicative through taking the change value from 2003 to 2004 as the base period value, and the accumulated values this paper obtains are the annual urban green TFP, EC and TC values. The results are shown in the following "Table II":

TABLE II. ACCUMULATED VALUES OF ML, EC AND TC INDICES OF CITIES THAT ARE GROUPED BY SIZE FROM 2004 TO 2016

Year	Megacity (TD)			Big City (D)			Medium-sized City (Z)			Small City (X)		
	ML	EC	TC	ML	EC	TC	ML	EC	TC	ML	EC	TC
2004	1.17011	1.01052	1.13826	1.19950	1.00915	1.17714	1.15467	0.96812	1.15604	1.34481	1.17458	1.13907
2005	1.41395	1.01242	1.36192	1.36527	1.00686	1.33500	1.33724	0.99554	1.29676	1.50396	1.13061	1.32867
2006	1.61904	1.03364	1.52280	1.47235	1.00794	1.43818	1.45806	1.04041	1.35346	1.61549	1.15703	1.37982
2007	1.93417	1.08475	1.69993	1.73479	1.01584	1.67988	1.67463	1.03051	1.57240	1.91961	1.18860	1.59292
2008	2.45776	1.08093	2.17034	2.15832	0.97088	2.18016	2.06041	0.95648	2.07649	2.42231	1.13956	2.10493
2009	2.61935	1.05779	2.36372	2.30494	0.98873	2.28592	2.25792	0.97612	2.23338	2.64579	1.12706	2.32661
2010	3.32875	1.17899	2.68915	2.74403	1.01541	2.65026	2.64335	0.97625	2.61412	3.19101	1.21475	2.61280
2011	3.79241	1.05960	3.44350	3.23514	0.95570	3.32396	3.18094	0.93068	3.29972	3.80736	1.18588	3.18475
2012	4.22796	1.09656	3.70473	3.50151	1.00869	3.40623	3.43050	0.98940	3.35285	4.11708	1.15861	3.51938
2013	5.23041	1.18801	4.22647	3.81812	1.05989	3.52879	3.73045	1.02727	3.51213	4.29766	1.19898	3.54751
2014	4.64176	1.11108	4.02356	3.82356	0.99124	3.77843	3.70643	0.93782	3.82234	3.87142	1.03637	3.70994
2015	5.75682	1.14289	4.87383	4.38812	1.03284	4.16472	3.95164	0.93619	4.08232	4.38913	1.05184	4.13091
2016	7.31845	1.07576	6.59850	5.29502	1.02312	5.06941	4.72491	0.94577	4.83170	4.73834	0.99947	4.71282

As can be seen from "Table II", the green TFP index and technical accumulated value of the four groups of cities show an upward trend year by year; from the change of EC accumulated value of efficiency, there is a slight overall increase in mega-cities and big cities, while there is a slight decline in medium-sized cities and small cities.

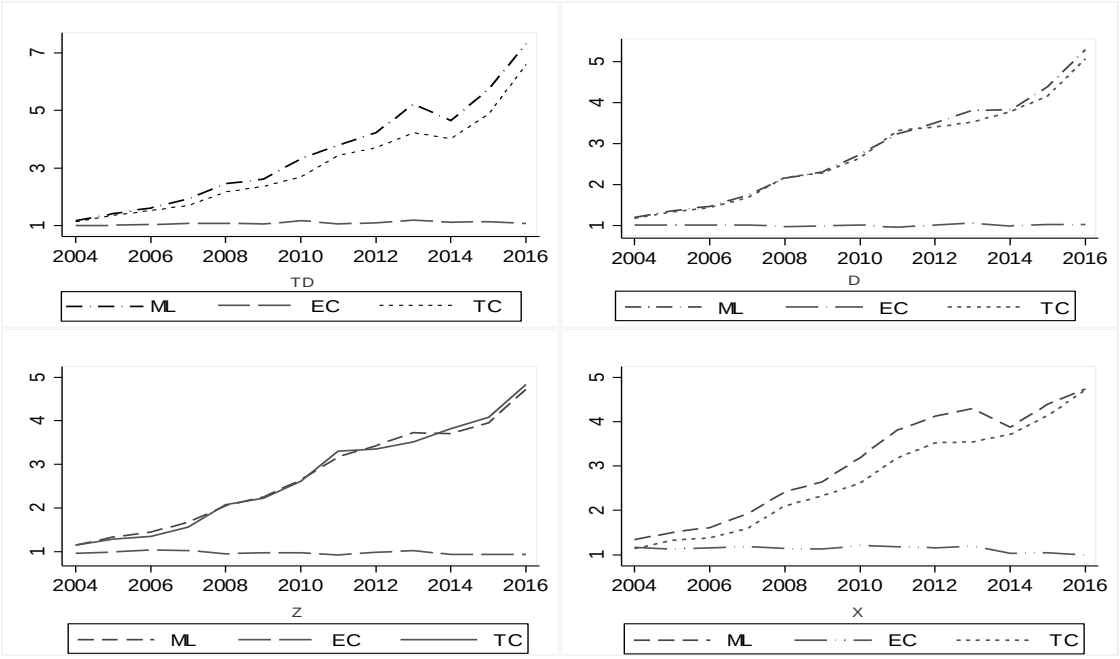

Fig. 2. Broken line graph of accumulated value of ML, EC and TC indices in four groups of cities from 2004 to 2016.

"Fig.2" is a broken-line graph charted by the accumulated value of green TFP index, EC index and TC index for four groups of cities: megacities, big cities, medium-sized cities and small cities from 2004 to 2016. The trend of ML index, EC index and TC index of the four groups of cities is basically the same, and the green TFP and technology are on the rise as a whole. Among them, the efficiency and technology of megacities and big cities all has played a driving role for the increase of total factor productivity that mainly depends on the improvement of technology and efficiency improvement is relatively small. The ML curve of big cities is above TC curve, and the ML curve of big cities basically coincides with EC curve, which also shows that the degree of efficiency improvement of megacities is higher than that of big cities; the efficiency of medium-sized cities and small cities fluctuates frequently in different years, and it mainly decreases, thus indicating that the growth of green TFP of medium-sized cities and small cities mainly depends on the improvement of technology. The above analysis shows that the growth of green TFP in four groups of cities is mainly driven by technology, and efficiency has become a bottleneck restricting the growth of urban green TFP.

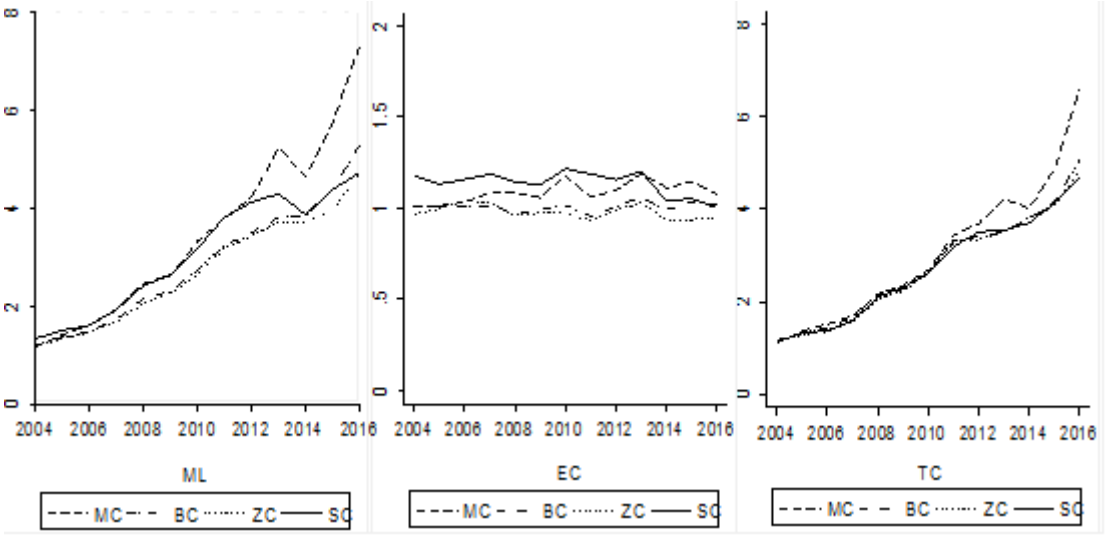

Fig. 3. ML, EC and TC index accumulated comparative broken-line graphs of cities grouped by scale from 2004 to 2016.

From the break-line graph of "Fig.3", the green TFP of the four groups of cities shows an obvious upward trend in general. From the perspective of the time interval, the growth rate of the four groups of cities differs slightly from each other in 2004-2006. After 2006, there began to be greater differentiation among them as evidenced by the growth rate of

megacities is the fastest, the growth rate of big cities is more consistent with that of mega-cities before 2012, and after 2012, there is a gap between the two to a much greater extent; from the perspective of efficiency change, the accumulated value of four groups of urban efficiency change is characterized by stable fluctuation, megacities and big cities witness a small increase, and medium-sized and small cities witness a small decline. In addition, the efficiency of four groups of cities declined significantly in 2008, 2011 and 2014, which may be affected by the financial turmoil and natural disasters in 2008, the widespread ice disaster and Sichuan earthquake, the European debt crisis in 2011 and the sharp fall of international commodities in 2014, etc.; from the perspective of technological changes, the overall takes on the "gradient" characteristics as evidenced by the mega-cities are better than the big cities, big cities are better than medium-sized cities, medium-sized cities are better than small cities. Four city groups began to differentiate in 2011 as evidenced by the megacities have seen promotion to a greater extent and widen the gap the other three groups of cities, there has been a significant decline in 2014 that it reaches almost the same level as the other three groups of cities, and then it sees rapid growth. The differences among the four groups of cities are mainly due to the differences in resource concentration degree, technological input, talents and market allocation among cities of different sizes, which leads to the gap in efficiency and technological development speed, and finally reflects the differences in the growth of green TFP.

V. CONCLUSIONS AND SUGGESTIONS

According to the previous analysis, the green TFP growth power of four groups of cities grouped by city size mainly comes from technological progress, and efficiency has become the bottleneck restricting their growth; different cities of different sizes all show different growth trends, but there are significant gaps in TFP growth, efficiency and technology, the overall takes on the "gradient" characteristics. Over time, the inter-city disparity is characterized by repeated fluctuations, which widen for a while and narrow for w while. Based on the above analysis results, this paper puts forward the following suggestions:

A. Giving Full Play to the Role of Market in Resource Allocation and Further Improving the Level of Resource Allocation

We should take "making the market play a decisive role in the allocation of resources" as the focus of economic system reform, further deepen the reform of market access system, accelerate the establishment of fair, open and transparent market rules; continue to promote the transformation of government functions, and stimulate the innovative vitality of various market entities to the greatest extent.

B. Full Consideration of the Actual Development of Various Regions and the Formulation of Economic Policies in Line with Local Conditions

The formulation of development policies must not be "one-size-fits-all". We should fully consider the differences between different regions, refine the analysis of regional factors, focus on classification guidance, and improve the accuracy of policies. At the same time, we should make them form a comprehensive positive impact and integrate local characteristics to coordinate development policies with the characteristics of local economic development.

C. Speeding up the Pace of Construction of Small and Medium-sized Cities and Narrowing the Gap Between Cities

Because small and medium-sized cities are limited by their size, the agglomeration effect cannot be brought into full play and the growth is slow. Therefore, we should speed up the pace of urban construction as evidenced by we will increase the construction of public infrastructure, improve social security, cultural and educational services, medical and health services, housing, public safety and other services, and establish and improve the personnel training and introduction system. At the same time, we should attract the migration of population and the gathering of talents to attract more high-quality resource elements to improve the level of economic development.

REFERENCES

[1] Charnes A, Cooper W W, Rhodes E. Measuring the efficiency of decision-making units[J]. European Journal of Operational Research, 1979, 3(4):339

[2] Chung, Y.H., Färe, R., Grosskopf, S. Productivity and Undesirable Outputs: A Directional Distance Function Approach[J]. Journal of Environmental Management, 1997, 51, 229-240.

[3] Coe D T, Helpman E. Internationl R&D Spillover[J]. European Economic Review, 1995,39.

[4] Zhang Jun, Wu Guiying, Zhang Jipeng. Estimation of Interprovincial Material Capital Stock in China: 1952-2000 [J]. Economic Research, 2004, (10). (in Chinese)

[5] Li Cheng, Tian Mao, Liu Shengfu. The Impact of Real Estate Development on Capital Return Rate[J]. Symposium of Finance and Economics, 2014 (12): 38-45. (in Chinese)

[6] Shan Haojie. Re-estimation of China's Capital Stock K: 1952-2006 [J]. Research on Quantitative Economy and Technological Economy research, 2008, 25 (10): 17-31. (in Chinese)

[7] HALL R E, JONES C I. Why Do Some Countries Produce So Much More Output Per Worker Than Others?[J]. Quarterly Journal of Economics, 1999, 114(1):83-116.